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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

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The Progress of Science

Science and Weather Forecasting

THE best-known work done at the Central Forecasting Office at Dunstable is that of collecting and collating information from numerous widespread stations and then issuing synoptic charts and forecasts (see DISCOVERY, June 1950, p. 196). For these the usual surface information about temperature, pressure, humidity, cloud, etc, is collected by telephone and teleprinter. There are also extra devices not so widely publicised, such as the radiosonde, which is a system based on the free ascent of a hydrogen balloon a few feet in diameter, holding a radio transmitter and meteorological instruments, and sometimes a radar reflector as well. The balloon is released periodically and from it information about the variation of temperature, etc. with height can be obtained as well as information about wind speeds and directions at various heights. The balloon eventually bursts. The apparatus then descends by parachute. (Anyone finding it and returning it is paid a reward of five shillings.)

Another device is a radio direction-finding apparatus for detecting thunderstorms. A flash of lightning emits electromagnetic disturbances that spread over very large areas. They are heard in ordinary radio receivers as 'atmospherics'—the crackles of distant lightning discharges. The operation of the direction-finding apparatus is therefore called 'sferic' observation. Anyone who has studied radio theory knows that the oscillatory discharges of a lightning flash occur at a lower frequency than that of any signal used in radio communication and broadcasting. For example, the frequency of medium-wave broadcasts are between 1200 and 600 kilocycles per second, one kilocycle being a thousand cycles. The frequencies of long-wave broadcasts are between 300 kc/s and 150 kc/s. In contrast to these, the radio receiver used for sferic observation is tuned to only 12·5 kc/s, corresponding to a wavelength of 24,000 metres. The sferic receiver is therefore especially sensitive to the oscillations of a lightning discharge and does not respond to any signals used in broadcasting and communication.

The lightning 'signal' is received on frame aerials set at right angles, one aligned north and south, the other east and west. The strength of the received signal at each aerial depends on the angle between the aerial and the incoming wave. For example, if an incoming signal is on a line from SSW to NNE, the ratio of strength in the north-to-south aerial to that in the east-to-west aerial would be about 9 to 5. Each part of the signal is detected and amplified very carefully, so that the initial difference between the two parts is accurately maintained. This is essential for the correct working of the direction-finding system. The amplified results are applied respectively to the Y and X plates of a cathode-ray tube. With no signal, the cathode-ray spot is central. When a signal is received, the vertical deflection is proportional to the north-to-south part, and the horizontal deflection to the east-to-west part. The spot is deflected accordingly to a certain position, just like the plot of a point in an ordinary graph. But the signal is an oscillation and so the spot travels backwards and forwards along a straight line through the centre. The screen of the cathode-ray tube is a special one having a slight persistence, so that the light from the spot is maintained for a fraction of a second. Thus a line of light is seen quite clearly for a moment. A scale of degrees round the circumference of the cathode-ray screen enables the direction of the incoming signal to be read by the operator.

This direction is ambiguous because it only defines the line along which the signal is received. For example, a signal on a line SSW to NNE could be to the south-south-east of the receiving station or to the north-north-east. This ambiguity causes no difficulty, however, because there are four sferic-observation establishments in Great Britain. So a fix is obtainable from the intersection of four directional lines. The apparatus was originally designed by Sir Robert Watson-Watt. It has a very great range, for a signal from a storm up to 2000 miles away can be detected. With it the course of a severe thunderstorm can be traced as it builds up and dies.

Theoretical research at the C.F.O. is done in the Napier Shaw laboratory, opened this year. All this research centres round forecasting, with two main problems under investigation. One is the testing of theoretical formulae in connexion with short-wave forecasting, the main purpose being to improve the accuracy of such work. The other is the testing of formulae aimed at accurate long-range and medium-range (4-day) forecasts. Both problems have interrelated sub-problems. There is, for example, a formula connecting fog with night minimum temperature. This is

tested against actual fog distribution as found. There is also a formula originated by Charney and Elliassen for predicting the vertical height of atmosphere at which the pressure will be 500 millibars. So far, results seem to suggest that empirical forecasts are more accurate than ones derived from the formula, for which rather considerable claims have been made.

This calculation of the height of atmosphere at which the pressure will be 500 millibars shows how important three-dimensional analysis has become. Changes in the upper atmosphere are important in the prognosis of weather changes, and for long-range and medium-range forecasting they are probably as important as surface measurements. Dr. Sutcliffe, director of forecasting research, has ideas of his own for medium-range forecasts, and the problems being investigated by the research staff are very much connected with his ideas.

Research into long-range and medium-range forecasting is a long-term affair. It is too early to say anything about the results so far achieved, and no guess can be made about the time we shall have to wait before long-range and medium-range forecasting is accurate enough to be part of the normal forecasting service.

Victor Grignard 1871–1935

THE organic chemist has an advantage over his inorganic colleague in being able to perpetuate his name by having it given to some particular type of reaction of which he is the discoverer. The organic chemist is thus on the same footing as, for instance, the anatomist, for many organs of the human body are named after the famous anatomists who discovered them. The inorganic chemist who wishes to create a memorial for himself in this way must hope, at the best, to have his name given to some particular reagent, such as Caro's acid, Fehling's solution, or Peyrone's salt.

The honour of giving a name to an organic reaction has, perhaps, been rather too widely accorded, for some named reactions are of limited importance. No criticism applies, however, to a particular type of reaction which is just fifty years old this year. This is the Grignard reaction, known to every student of organic chemistry, and named after the famous French chemist Victor Grignard. The Grignard reaction is indeed one of the most versatile and useful weapons in the whole armament of organic chemistry and its discoverer was awarded a well deserved Nobel Prize in 1912.

Like many great discoveries, that of Grignard was essentially very simple. He found that in the presence of ether, magnesium metal will react with many organic compounds of chlorine, bromine, or iodine, displacing these elements and forming an organic magnesium compound soluble in ether. From this ethereal solution can be made, by treating the dissolved magnesium compound with appropriate reagents, an extraordinarily wide range of products. For example, from the simple Grignard reagent, ethyl magnesium chloride, can be obtained ethane, propionic acid, ethyl mercaptan, propyl alcohol, propionaldehyde, and many other derivatives. Not only is the method very versatile, but it has the important additional advantages of simplicity, economy in both time and materials required, and a high yield of the final product.

Comparatively recently the Grignard reaction has found industrial application, for certain carbon-silicon derivatives of chlorine will react with magnesium in ether in the same way as the purely organic compounds. By this means a number of important silicones have been prepared. This is the only successful commercial application of the reaction which we have been able to trace. Actually an American company has used it to manufacture phenylethyl alcohol, but the reaction had to be modified by leaving out the ether. (In this reaction ether has to be water-free, otherwise unwanted by-products are produced by hydrolysis; and ether in this condition readily forms explosive peroxides. Higher ethers have been tried, but these form peroxides even more readily, and the peroxides are poisonous when they are not explosive!)

The story of Grignard's original discovery is of considerable interest. In 1898 Professor Barbier at Lyon had been investigating the possibilities of using metallic zinc as an intermediary in organic reactions but, like others before him, found that results were variable and discouraging. Substitution of magnesium for zinc seemed to have some advantages but again the results were unsatisfactory and Barbier did not feel justified in publishing the results of his experiments. Two years later he suggested to his pupil Grignard that he might continue the researches; as Grignard said later "he was given a bone to gnaw". Within a year the pupil had brought the master's half-discarded research to a brilliant conclusion. The essence of his discovery was to discard zinc altogether in favour of magnesium and to carry out the reaction with it in two stages instead of one as earlier workers had attempted First he prepared the organic magnesium compound in ethereal solution; then he treated it further to obtain the products he desired.

When Grignard died in 1935 he had completed a monumental work on organic chemistry, the twenty volumes of his *Traité de Chimie organique*, which is still an important work of reference. His reaction is, however, a more fitting memorial. The *Traité* deals only with established organic chemistry; whereas the famous reaction still has a profound influence on its future.

Thunderstorm Census

BECAUSE of the damage which lightning can cause, thunderstorms are of direct economic importance as well as scientific interest, and for this reason the British Electrical and Allied Industries Research Association started systematic thunderstorm observations some time ago. In July 1948 the Research Association appealed in our columns for readers to take part in the project, and DISCOVERY readers account for a big proportion of the 375 voluntary observers now regularly sending the Research Association information about the occurrence and severity of thunderstorms.

The Research Association has just published a report on the thunderstorm observations for 1949. Fig. 1, reproduced from the report, shows the monthly variation in thunderstorm activity during the year. It will be seen that this activity reached a peak in May and another peak in September. Fig. 2 shows the distribution of thunderstorms over England and Wales in 1949. This map is not as reliable as it might be owing to the fact that it has not been possible to recruit a sufficiently large number of observers uniformly distributed over the country. It is hoped to fill

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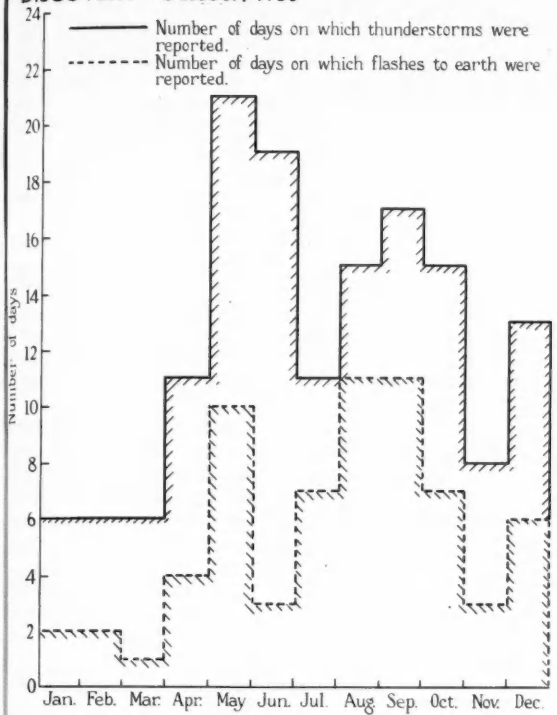


FIG. 1.—Monthly variation of thunderstorm activity in 1949.

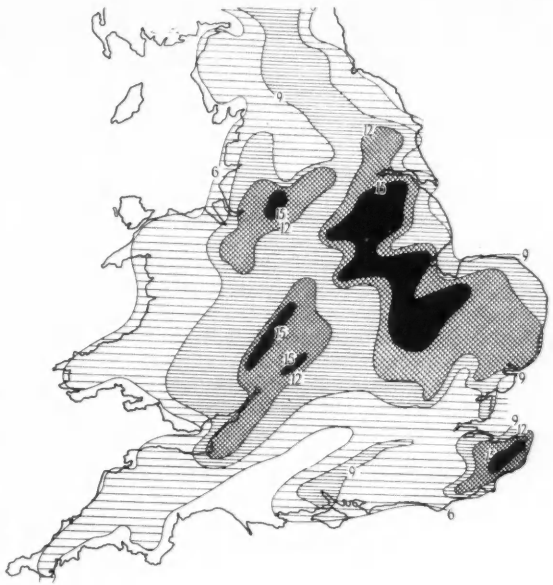


FIG. 2.—Distribution of thunderstorms over England and Wales, 1949. Black areas, over 15 days with thunderstorms; crosshatched, 12–15; narrow lines, 9–12; widespread lines, 6–9; unshaded, less than 6.

the gaps during this year, and anyone in England, Wales or Scotland who is interested in keeping records of thunderstorm activity in the knowledge that those records will be put to a good purpose should write to: The British Electrical and Allied Industries Research Association, 5, Wadsworth Road, Greenford, Middlesex, marking the envelope "Thunderstorm Observations".

Science on Television

AN experienced broadcaster has described a speaker's first visit to the studio as like a visit to the dentist, but with this distinction, the B.B.C. does not provide an anaesthetic to dull the strange sensations that arise from the unfamiliar situation in which the speaker finds himself! Many science broadcasters will no doubt agree that this describes their feelings in the studio, but what are they to feel when they know that they are to be seen as well as heard by hundreds of thousands of viewers? New and perhaps unforeseen complications arise. Let us cite the following hints recently given to performers before the television camera. "Plain business suits are the best choice for science programme participants. If possible, suits should be brown or dark grey in a soft material . . . a broad plaid or heavily checked suit is bad. If the pattern is bold, it will set up a confusing background for small items of demonstration and cause a distracting series of lines on television screens. A grey, blue or tan shirt is preferable to a white one . . . a tie of a bold pattern in a lustreless fabric, not satin, is the one which shows up best. The broad patterned tie is not confusing like the suit because such a small area of it shows, and it makes a definite division between coat and shirt."

This comes from the recently published *Science via Television* (Johns Hopkins Press, Baltimore, U.S.A., and Oxford University Press, London, 1950). Its author is Lynn Poole, Director of Public Relations at the Johns Hopkins University, where it is already possible to take a course in television production.

In line with other media for informing the public about science, America's various television networks are trying to discover how to satisfy the increasing and widespread demand for knowledge of what scientists are doing.

Among already well-known American television science programmes there is NBC's "The Nature of Things" and various programmes sponsored by the American Chemical Society such as "Science Page of the Week" from Los Angeles and "Headlines in Chemistry" from Minneapolis. Most significant perhaps so far has been the Johns Hopkins Science Review carried by CBC.

The result is that, unlike Britain with its single television organisation, there are in America sufficient individual stations and potential contributors to science programmes to merit the publication of a 'how-to-do-it' book devoted solely to the presentation of science by television.

Science via Television is the result of the experience gained over a longish period in the production of the Johns Hopkins Science Review. Its author describes it as a practical guide to the preparation, planning and production of a television programme. As such it might well be studied with benefit by scientists in this country where by contrast there is not, as far as we know, even a guide to the preparation of sound radio scripts.

Let us first examine the idiosyncrasies of television. At the present time there seems to be a widely held belief among scientists that television is *par excellence* the medium for the mass dissemination of scientific information and they feel that a few minutes seeing may be of more value than hours of listening. But, while this may be conceded, and the desire to inform and educate may underlie any science television programme, scientists have to remember that, to quote Lynn Poole, "television is show business". It has to compete for viewing time with sporting events, the big fights, music-hall, and a dozen and one other forms of entertainment. So an absolutely fundamental problem for the would-be television scientist to solve is the presentation of his material with all the care and skill and imagination that will make it bear comparison with the slickest of entertainment productions. Moreover, this means that as much care has to be lavished on a television programme as on the making of a film, but there is this difference: the film will put his efforts on permanent record while the television production is evanescent.

Such productions obviously take time—lots of it—and the value of the time consumed in the production of such a television programme is something about which scientists will no doubt think carefully. Even allowing that the effort is worth while, can a busy scientist afford to give the time demanded by the nature of the medium? This demand on the already overworked scientist is clearly brought out by Lynn Poole. Few viewers or indeed listeners are aware of the essential preliminaries that go to make the successful programme. There is no very obvious reason why the figures quoted in this American book should be different for British scientists. These show that before the Johns Hopkins Science Review put out a single half-hour programme on supersonic flight 200 man-hours had been spent on what the author describes as "patient drudgery and unglamorous conferences". So it is abundantly clear that those scientists who undertake the presentation of their subject for a wide public are not to be considered as the glamour boys of science but rather as responsible drudges to whom it is a matter of conscience to find the necessary time and inspiration. To them this book cannot but be helpful. But not to them alone, because anyone approaching the problem of the presentation of science to a wide audience is virtually faced with the same difficulties. Let us look at what these are as set out by Lynn Poole.

First there is the definition of the purpose of the programme, and such is the competition for air space that here many ideas must inevitably be shot down because there is no better reason for putting them on the air than that they might be interesting—and interesting rather to the televisor than to the televiewer. With the purpose of the programme defined, there is the form it is going to take. Here it seems obvious that it is essential to concentrate on those parts of science that make good viewing. But as its author cautiously points out, there may be many activities in the laboratory which, though fascinating in themselves, might offend at the viewing end. This is a moot point, open to debate, and the attitude on the two sides of the Atlantic may turn out to be quite different. Would a preview of an appendectomy increase or decrease the morale of a future victim? Might not a sympathetic understanding of the role of experimental animals in relation to the advances of science and their use by humanity make for a better understanding of the position of the vivisectionist? Be that as it may, the selection of the subject calls for careful consideration and that is only the first step. The selected subject has to be developed into a theme. This calls for ruthless economy so that while avoiding the pedantry of the lecture theatre irrelevant material is not introduced to confuse the viewer who cannot stop the broadcast to ask questions about the significance of the bits he doesn't understand. The same is true of the selection of the visual material.

It is only with these problems out of the way that the actual creation of the broadcast can start and the author undoubtedly has much to say that is useful both to would-be broadcasters and televisors. He omits, however, the whole question of who is to do the writing. The scientist knows little of the requirements of writing for radio, the writer, if he be writer only, less of science. This is particularly pertinent in relation to some of the examples given by Lynn Poole. What would Macaulay's schoolboy say of this?

"In a sequence for a programme the demonstrator wanted to show first that carbon dioxide is given off in gas form by dry ice, and second, that the gas is lighter (*sic*) than air. It was decided to inflate a balloon with the gas. . . . He broke a piece of dry ice into bits which he dropped into a test tube containing a few drops of water. Next the lip of a balloon was slipped over the open end of the tube. The gas rapidly inflated the balloon which was then removed from the test tube, fastened at the lip and released to prove that it would rise and was indeed lighter than air."

Perhaps this sequence would better have been included in the much-quoted broadcast "Seeing is not Believing"! Indeed the hints on the preparation, planning and production of television programmes on science seem much better than the products of the given canons. Warning is given against the phoney and the irrelevantly spectacular, but at the same time Tesla coils, lie detectors and lashings of liquid air and solid carbon dioxide appear in the scripts. This may have a certain if doubtful dramatic value, but a very fundamental point of policy with regard to the experiments shown in television broadcasts has yet to be answered, that of, to fake or not to fake.

In an experiment purporting to show psychogalvanometric effects is it legitimate to get the 'guinea pig' to squeeze the electrodes a bit harder at the appropriate time so as to get what appears to be the anticipated response? If it requires a concentration x of insecticide to kill half the mosquitoes present, is it justifiable to use a concentration $2x$? Where would science be today if Harvey, Arrhenius, Ehrlich, or Rutherford had only got the results they expected? If scientists are to be shown at work it must be as men of truth and the public will be no less appreciative if their experiments don't always come off the first time. Heaven forbid that television should make them into conjurers to be discredited if they fail to do what the audience expects.

In spite of these contradictions *Science via Television* could undoubtedly be a useful book for the would-be performer at Alexandra Palace. But with all that settled, there is still one fly in the ointment; such is the effect of devaluation that his advice will cost him twenty-eight shillings, for the hundred and ninety pages of it within paper covers.

Wild Animals in Captivity

Dr. EDWARD HINDLE, F.R.S.
Scientific Director, Zoological Society of London

THE interest evinced by the public in the exhibition of wild animals in Great Britain may be gauged by the number of visitors to the zoological collections in London, Bristol, Chester, Edinburgh and Glasgow, as well as various commercial zoos and circuses. The annual attendance at the Zoological Gardens, Regent's Park, for example, is now between two and three million, exceeding the total number of visitors to all the museums and art galleries in London, and each year it is reckoned that at least one in four of the population of the whole country pays a visit to either a zoo or a travelling menagerie. The arrival of a giant panda, a baby elephant, or a giraffe, often arouses more popular interest than the most highly placed political figure, and during the past six months more photographs of Brumas must have appeared in London than of any human celebrity.

In view of such general interest it is rather unexpected, therefore, to find that until very recently no book describing the general principles of how best to keep wild animals in captivity has ever been published. Professor H. Hediger, the Director of the Basle Zoological Gardens, who has long been known as a student of animal psychology, is the first to produce such a book, *Wildtiere in Gefangenschaft*, with the express purpose of laying the foundations for a more exhaustive treatise on zoo management. This represents the first attempt by a qualified zoologist to approach the subject from a scientific viewpoint, and an English translation, revised and brought up to date by the author, has now appeared under the title *Wild Animals in Captivity*.

The title at once focuses attention on one aspect of zoological gardens which is often under discussion. Captivity is a word which at once arouses sympathy, and calls to mind some of the famous captives of romance, for whatever the reason there seems little doubt that a number of people regard animals in zoological gardens as innocent convicts and a director of a zoo as a kind of prison governor.

It may come as a surprise, therefore, to most readers to learn that the popular conception that in nature animals are fancy-free and range at will over wide areas, is very far from the truth. Until recently very little was known of the actual living conditions of animals in their natural state. However paradoxical it may sound, the truth is that the free animal does not live in freedom, neither in space nor as regards its behaviour towards other animals. Each species, in addition to having a very definite geographical distribution, is confined to certain limits within its main range. The seasonal movements of migrant animals, and especially birds, should not be thought of as pleasure trips. They are in fact compelled to go on their exhausting migrations as a result of a fixed rhythmic cycle, and every year these migrations involve the death of countless numbers of individuals that are not equal to the exacting demands of these long journeys.

Similar factors are involved in the restriction of animals to particular territories—the living area. This territory may be occupied by only a single individual, or by a pair, or by a social unit; in the latter case dominated by the leader of the group. Although theoretically an animal may be able to move about within the whole area occupied by the species, in most cases it is prevented from doing so by a combination of factors. In the case of mammals, each individual or social unit occupies only a certain territory which is usually demarcated in some way, and any intrusion on this area is strongly defended.

The methods employed for defining territories vary in different animals, but optical, acoustic, olfactory, or various combinations of these, are the most usual. Territorial demarcation by acoustic means occurs in many animals. The croaking of frogs apparently acts as an indication of living space, and among reptiles the roar of the alligator seems to have a similar significance. The song of birds during the nesting season is one of the best known examples, and in the case of the wren, its song alone seems to be sufficient to keep others out of its territory. A similar method is used by certain gibbons, including the siamang, and also by howler monkeys. Among these, shouting matches take place between the males of two groups and continue without actual fighting until one of the groups retreats.

The favourite method of demarcation in most mammals, however, is olfactory. For this purpose excrement or urine may be used, or scents produced by special glands (Fig. 1). When secretions are used they are often deposited on definite places in the territory, and the scent is continually renewed. The males are usually responsible for this upkeep of scent markings, and any glands or special organs for the distribution of scent are much more developed in them than in the females. In fact most females lack these secretions. The Indian antelope is a good example of an animal using this method, for both sexes possess a large pair of glands situated below the eyes which secrete a highly odoriferous resinous substance. In nature this secretion is deposited on the lower branches of trees and bushes, but in captivity the males often mark out their territories by depositing this secretion on the bars of their enclosures. The slow loris has no special glands, but employs urine for the same purpose. When placed in a clean cage it never rests until it has sprinkled the floor and bedding with urine and so marked out its territory with boundaries of scent. Incidentally, this is another example of how one can go wrong by applying one's own idea of comfort to animals, for to a slow loris a clean cage means actual discomfort.

By paying attention to the psychology of an animal, and particularly its methods of marking its 'territory', it is possible to impart to a well-kept animal in a zoo a feeling of ownership of its cage or enclosure, rather than the sense of being a prisoner. Even when there is no obvious indication of territory, the dangers of moving an animal from one cage to another are well known to all who have had experience of animals in captivity, for once an animal has settled down in its own particular quarters it usually objects to being moved. This is one of the reasons why everyone with knowledge of zoo-keeping avoids as far as

FIG. 1.—A Wisent bull rubbing scent on a tree to mark its territory.

possible the transference of animals from one cage or enclosure to another.

In addition to having some idea of the territorial requirements of animals in their wild state, a knowledge of sociological factors is of fundamental importance in the problem of keeping wild animals. Man is the universal enemy of nearly all animals in the free state, and as a result most newly captured animals show some kind of escape reaction in his presence. When captured, the previous world of a wild animal is utterly destroyed as it comes into an entirely different environment pervaded by man. Under such circumstances flight from man, the enemy, becomes meaningless, and the main problem confronting the animal is the reconstruction of a world to fit its new environment. Once this change of significance of man has been accomplished, it becomes adapted to the different circumstances, and a new harmonious state may develop between the animal and its surroundings. The life of an animal which has reached this state of harmony in captivity is just as complete, or incomplete, as that of an animal at liberty. For animals born in captivity there is obviously no such discrepancy between behaviour and environment.

Man with his anthropomorphic tendency has always imagined that the chief factor of an animal's life in captivity is restriction of space. This has received far too much attention in the past, while on the other hand the quality of the space has received too little. The ecological analysis of freedom has shown that the free animal has not an unrestricted amount of space at its disposal; simply a territory of limited extent varying in size from a few square yards to hundreds of acres, according to the species. It is obviously impossible to provide each animal in a zoological garden with a space the same size as its natural territory, and therefore it is necessary to consider some of the indirect or secondary results of confinement when considering the quality of space.

In freedom, the wild animal has the urge to escape from an enemy, especially from man, as soon as the enemy gets within a certain distance, which may be called the flight distance. Since the size of most cages does not allow for the full flight distance, this fear of an enemy has to be overcome by taming, which eventually may reduce flight distance to zero. A tamed animal loses its urge to run away from human beings and settles down in a very much smaller space than its untamed companion, and a thoroughly tame animal in a small cage will not be disturbed by the approach of man, but is more likely to press against the wires, showing a desire to be fondled.

Of course the well-being of a captive animal also depends upon the possibility of satisfying those occasional bursts of activity that are essential to the health of the species, but the space necessary for this is often greatly overestimated. In spite of the space available for the animal in captivity being much less than its natural territory, experience shows that in seemingly cramped quarters many animals thrive longer than in nature and are able to breed. This raises the question as to why the territories of free roaming animals are so extensive. It should be remembered in this connexion that the free animal has to forage for itself. Moreover, it must live on the surplus provided by its territory. Whatever one's personal prejudices, biological facts must come before anthropomorphic ideas concerning the animal and freedom. Even the eagle, a typical example of free and unrestrained flight in boundless space, does not fly about at will in its territory, but is driven chiefly by the urge to get food. If food is plentiful, this urge disappears and it gives up distant foraging expeditions.

Captive Animals Live Longer

Significantly enough, the animals which range over wide territories, such as the elephant, the large ungulates, and the birds of prey, are amongst the longest-lived animals in zoological gardens, and some of the easiest to keep in captivity. It is almost certain that the maximum span of life of many animals is obtained in captivity and not in the wild state. In the wild, very few animals indeed die of old age, whilst the results of post-mortem examinations show that quite a number do so in captivity. This view is also supported by observations on the effect of different conditions on the ages of four common British birds, shown in the following table, taken from Stuart Smith's book *How to Study Birds*:

Species	*Greatest age (Aviary)*	*Greatest age (Wild conditions)*	*Average age (Wild conditions)*
Song-thrush	17 years	9 years	1½ years
Blackbird	20 years	10 years	1¾ years
Starling	15 years	9 years	1½ years
Robin	20 years	11 years	1–1¼ years

Man is apt to assume that in animals there is a need for movement, such as flying in birds, running in ungulates, etc., but it is necessary to distinguish activity resulting from internal necessity from that due to some external cause.

Examples of exuberant muscular activity include the play activities of many species of monkeys and the screeching parties of parrots, etc. The common marten and pine marten are also good examples of animals with super-abundant energy. The amount of exercise taken by mice, as judged by their turning of a wheel, has been shown to be directly correlated with the amount of food given to them. Some animals take very little natural exercise, and Antonius goes so far as to say that the lion needs so little that he refuses to take a step on his own if his daily food is provided for him. At any rate, there are a large number of animals which most certainly do not use up all the space provided for them in captivity, and through lack of external stimuli tend to move about far less than is good for them.

Another popular idea is that the bars prevent the caged animal from regaining its liberty, but the real truth is that in all animals born in captivity, or taken very young, this assumed longing for freedom cannot exist as they have never known it. Contrary to the idea mentioned above, experience with all kinds of animals in zoos shows that animals that are set free, or even escape, often voluntarily return to their cages.

The limits of the cage simply mean a distinct demarcation of territory for the animal, and the space given to a caged animal is frequently defended against new arrivals as though it were its own property. That is one reason why it is risky to put new arrivals among animals that have already settled down. It is much better to put them into a new home altogether. This fact is important not only for zoo curators, but also for animal trainers in menageries. The circus trainer, when dealing with such large carnivores as lions and tigers, should always be the first to enter the empty training cage and ostentatiously stake a claim to the cage as his territory. Only then should the animals be let in. With regard to the dog, it is probable that he considers everything his property within his range of smell, and that where the dog shares house and home with a man, the dog's territory coincides with the man's. Birds provide numerous examples of defence of territory. Each year at the breeding season they mark out a certain territory, surrounding the nest or nesting place, and attack any rival intruders. In the case of the larger birds such as swans, cranes, etc., almost any living being, including man, may be attacked if entering this zone.

Keepers are not allowed to go into the cages of large predatory animals, not because the lions or tigers consider them as prey, but because they would attack them for having entered their territory. It is very noticeable that birds living in aviaries will readily feed within a few inches of spectators, who are outside the netting, but will panic if a stranger enters the aviary, even though he may be very much farther away.

The feeding of animals in captivity presents a somewhat difficult problem, for even when the exact diet is known, it is rarely possible to provide the variety of foods which are eaten in nature. In most cases it is possible to devise a substitute food, which of course must contain not only the necessary nutriment, but also suitable vitamins. The koala, which feeds mainly on certain species of eucalyptus leaves, is an extreme example of an animal with a very specialised diet, for which a substitute has not yet been found. The king penguin on the other hand, which in nature feeds mainly on small crabs and polyps, readily adapts itself to a diet of fish, and in some cases has actually survived on raw meat. Indeed it is very surprising what unnatural diets may be successful. Anteaters which in nature feed almost entirely on ants, do quite well at the London Zoo on a mixture of minced meat, eggs, milk and so-called ants' eggs—really pupae.

Deficiency diseases present a more serious problem, for little is known concerning the conditions governing the nutrition of many animals, especially reptiles and amphibians, and in many cases it is extremely difficult to determine the best diet. Chameleons, whose natural food is almost certainly insects, never live very long in captivity although fed on the somewhat limited variety of insect food available, which one would have thought to be adequate. The giant panda is another example of an animal which does not do well in captivity, in spite of being fed on what must be at least an approximation to its ordinary diet. The food requirements of animals are not necessarily a logical outcome of the body organisation, or way of life, but are often discovered by chance. It has been found, for example, that the young of certain ducks and sawbills need to have insects and probably crustaceans in their diet for the normal functioning of the oil gland. If they are fed solely on fish the young birds are unable to grease their wings properly, their feathers become wet, and they drown. Yet the reason for this is not very obvious, for it has also been shown in other experiments that the oil gland seems to play no part in making feathers waterproof.

The mechanical properties of food may be of importance for many animals, for example in rodents with teeth adapted for a hard diet. If such animals have too soft a food excessive growth of the teeth may result.

Many animals regulate the amount of food provided by laying up food stores. It is generally assumed that the animal remembers where it has laid up these food stores, but there is little doubt that in most cases these stores are found subsequently through subconscious not conscious memory. The squirrel, for example, makes a large number of stores, but when it needs to use one, searches at random among its various hiding-places, many of which it never rediscovers.

A very controversial topic is introduced by Professor Hediger in his chapter on animal training, which he regards as "healthy, expedient and attractive". A wild animal has to avoid enemies and to seek food, factors which suddenly disappear after capture. This monotony can be broken in a pleasant way by providing the animal with new interests, and training is considered to be the equivalent of sport and games to civilised man. The more complex an animal's psychology, the more it is likely to feel the enforced lack of activities, and the sooner it tries to do something for itself. Chimpanzees and other anthropoids are famous for the way they 'play to the gallery', and even the young ones forming the 'Chimpanzee's Tea Party' at the London Zoo take an obvious pleasure in the performance.

The good trainer is considered to create something out of the inimitable movements of the wild animal just as the artist does with his colours or the composer with his notes. The quality of training lies in the harmony of the animal-

[Continued on page 330

FIG. 1 (*Top*)—Photographic silver bromide grains enlarged 2500 times. FIG. 2 (*Bottom*)—The same as Fig. 1 after exposure and development.

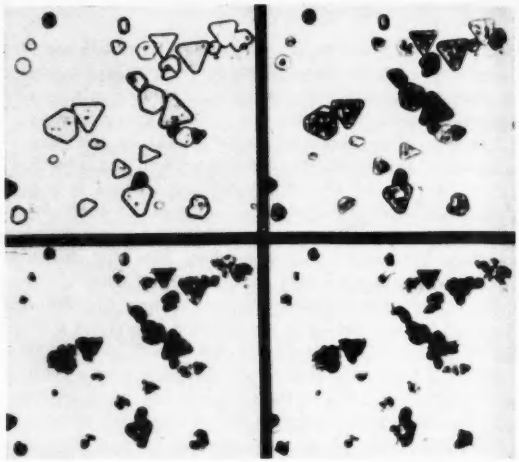


FIG. 3.—A photographic emulsion and its appearance after three different exposures in the last picture (of maximum exposure) the silver bromide grains have changed completely to silver.

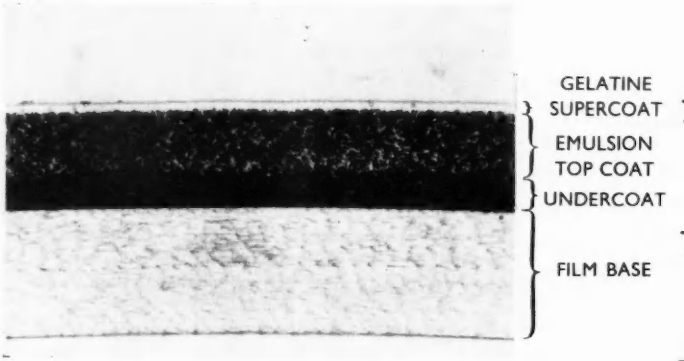


FIG. 4.—Cross-section through a modern fast film × about 150, the emulsion layers being swollen in water to about 10 times their normal thickness.

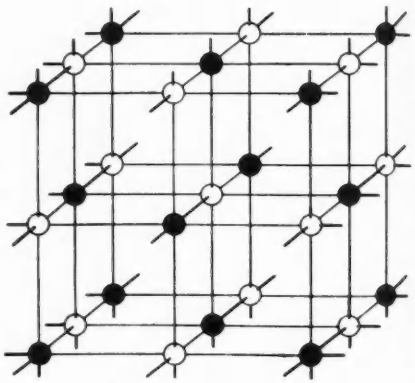


FIG. 5.—The crystal structure of silver bromide.

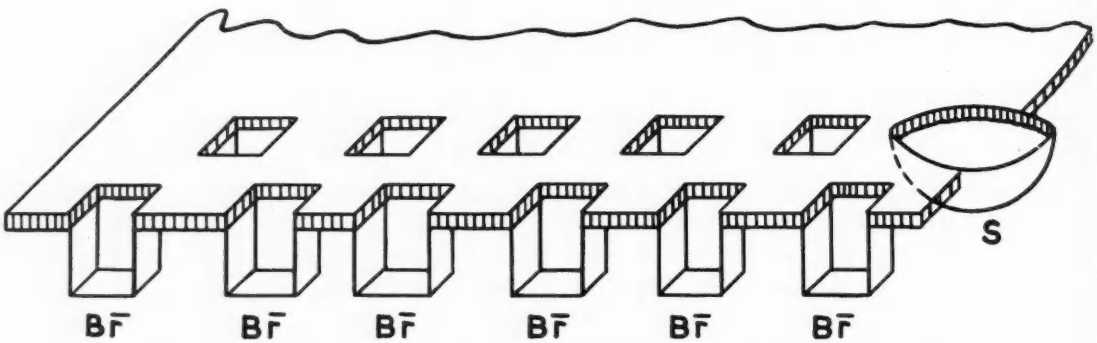


FIG. 6.—Diagram of the electronic structure of silver bromide. Absorption of light can raise an electron from its fixed position on the bromide ion on to the conduction level where it is free to roam through the crystal until it is trapped at the sensitivity speck *S*.

The Mechanism of the Photographic Process

W. F. BERG, D.Sc., F.R.P.S.

DESPITE the great and increasing scope of current applications of photography we do not yet fully understand the processes by which photography works. This may seem surprising when it is considered how long it is since the basic processes were first discovered and how much effort has been spent on photographic research since then. The reason is that the change brought about in photographic sensitised material on exposure to light is so minute that it is exceptionally difficult to study. As in the case of research on radioactivity it is necessary to consider individual atoms to understand the changes which are taking place.

The white or yellow coating found on photographic films, plates or papers is known as the emulsion. It can be removed by dissolving in hot water and if a drop of the solution so obtained is placed under a microscope it will appear very much like the photomicrograph in Fig. 1. The triangular and hexagonal crystals are the 'grain' of the emulsion and contain a mixture of silver salts; in fast emulsions this is mostly silver bromide, in slow ones mostly silver chloride. In the emulsions of normal photographic materials the grains are much more closely packed than they appear in Fig. 1 and after exposure to light some are turned into metallic silver by the developer, thereby making the photographic image. (Fig. 2). Thus the study of the photographic process necessitates the study of the individual grains.

The amount of light which is received by the photographic emulsion when it is exposed in a camera is normally so slight that no change can be detected in the silver bromide grains by any direct method. An impression is there, nevertheless; it is not visible, but can be rendered visible. This is described as a *latent image*. This image can only be detected by treatment with a developer which in the process obliterates it. In the heavily exposed portions of the emulsion many of the silver bromide grains are turned by the developer into black silver but in the lightly exposed portions, few or none are changed.

The grains are considered to be individually sensitive to light, each reacting independently of the exposure received by its neighbours.

Prolonged exposure to light does, however, produce a visible change in the grains, but only if it is at least 10,000 times that necessary to produce a latent image. This 'printing-out' by heavy exposure is caused by the production of metallic silver as seen in Fig. 3.

Research workers concluded early on in the history of photographic research that since these heavy exposures produce silver the smaller latent-image exposure presumably produces also silver, in correspondingly smaller amounts. It is now generally accepted that the latent image consists of minute amounts of metallic silver situated on individual silver bromide grains. This can be summarised as:

Silver bromide + light → metallic silver + bromine.

The elucidation in detail of the mechanism of this apparently simple process is one of the aims of fundamental photographic research and is the main subject of this article.

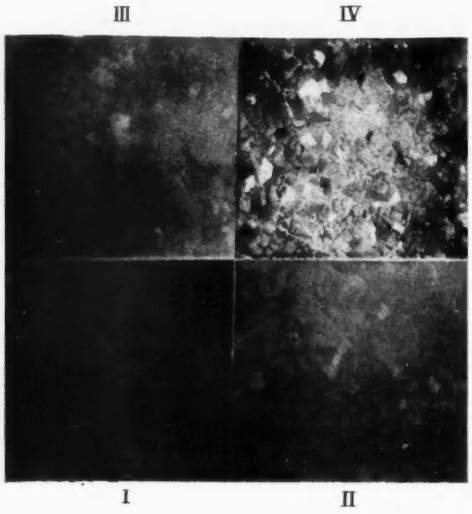
Even the smallest photographic images in common use, such as the individual pictures in a home-movie film, are made up of an astronomical number of grains. In each square inch of an emulsion layer there may be from one thousand million to a million million grains. In the ordinary emulsions used for amateur snapshots the average diameter of the grains is one twenty-five thousandth of an inch and in the dry emulsion each grain is separated from its neighbour by a distance roughly equal to its diameter. The grains are distributed at random about forty grains deep in the normal thickness of coating, as shown in Fig. 4 which is an enlarged cross-section of a modern fast film.

Although the grains are very minute they are large in comparison with the size of atoms and each grain contains some thousand million pairs of electrically charged atoms. These charged atoms, or ions, are built up in a regular pattern to form the silver bromide crystals as pictured in Fig. 5. This picture is incomplete since the ions might be better represented as closely packed spheres rather than separated dots.

The bromide ions are larger than the silver ions and largely determine the crystal structure. By simple proportion, from measurement of the amount of silver formed by long exposure of silver bromide, it is possible to calculate the amount of silver formed per grain of the latent image produced by a camera exposure. It is found that only a few hundred atoms are affected in each grain and it is clear now why it is so difficult to determine the presence of this silver directly. Nevertheless the presence of even these few atoms of silver is sufficient to enable the developer to convert the whole of the millions of silver ions in the grain to metallic silver; thus development is one of the most powerful methods of amplification known. These large figures are difficult to comprehend but some idea of the minute effect of a latent-image exposure on the emulsion can be gained from the fact that the cinema industry in Great Britain uses some hundreds of millions of feet of film per year, but the weight of the silver produced as the latent image in all this film is only a few grains. In other words, it would be necessary to expose about £140-million worth of film to produce an ounce of latent-image silver.

It was soon realised in the early days of photographic research that the latent image must consist of more than one atom of silver per grain. This was shown to be true by the following experiment. If two exposures are given to a single piece of photographic film in succession the number of grains made developable, i.e. the blackening produced on development, is often considerably larger than the total blackening produced when the same exposures are given to two separate pieces of film. Hence, the first exposure produces not only a number of developable grains, but also affects other grains so that they become sensitised and a second exposure makes them developable more easily than grains which have had no pre-exposure.

The hypersensitising effect of a pre-exposure is due to the production of a sub-developable latent-image. The existence of this sub-image is of some practical importance since it represents a genuine latent-image by which a picture can



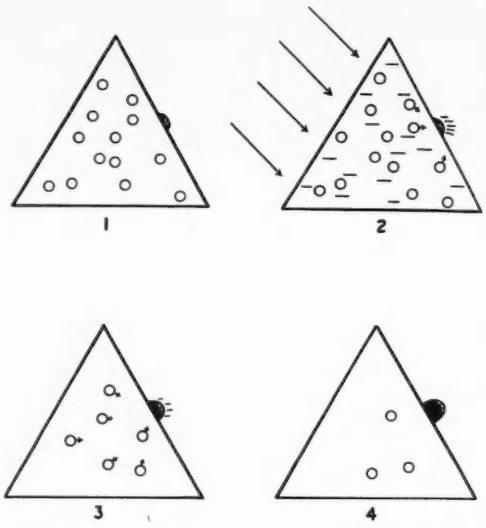
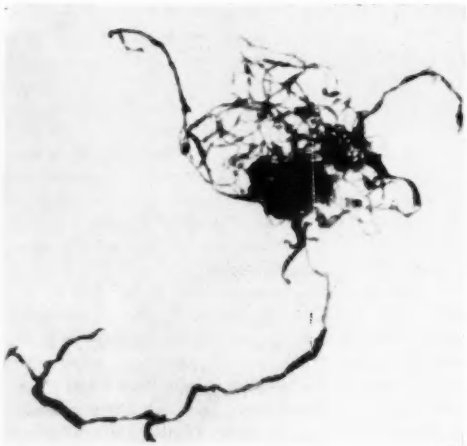


FIG. 7 (*Left*)—Practical application of the sub-image. I is the best print obtainable from a badly under-exposed negative; II portion of the same negative developed after a suitable uniform post-exposure to build up the sub-image; III as I after treating the negative in a uranium intensifier, and IV combining both methods of intensification. The speed increase is about 10 times.

FIG. 8 (*Right*)—The Gurney-Mott mechanism. O = ions in irregular positions; – = electrons; hatched body on the grain surface is the sensitivity speck.



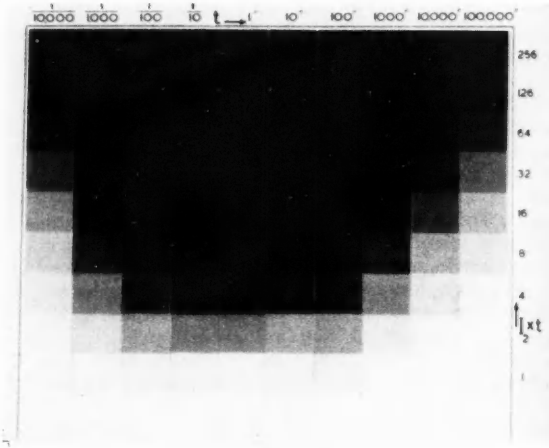


FIG. 9.—Electron micrograph of a developed grain. Enlarged about 12,500.

FIG. 10.—Change in sensitivity with time of exposure (reciprocity failure). Any one row of steps on the wedge images has received the same total amount of light but at varying rate.

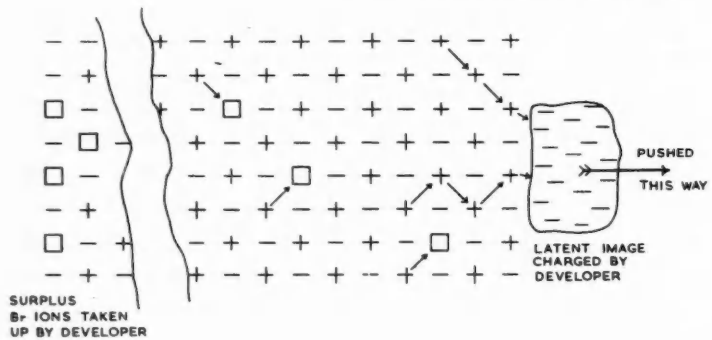


FIG. 11.—The mechanism of development.

be recorded, but it requires an additional exposure to light to render it developable. (Fig. 7).

We thus conclude that the latent image contains several atoms of silver. Since light is absorbed all over the grain, how is it that the isolated atoms of silver can come together to form a single metallic particle? The clue was given by an experiment made by Sheppard who found that certain impurities were necessary in order to obtain a highly sensitive emulsion. Sheppard demonstrated that these impurities were silver sulphide particles and suggested that they acted as collecting centres for the silver formed during exposure, in a manner analogous to the condensation of water vapour on soot particles to form fog. The discovery of the importance of silver sulphide as an impurity in emulsions constitutes one of the major advances in photographic knowledge and is of immense practical importance.

The knowledge so far described was gained as long ago as 1925 and although many attempts were made to discover by what mechanism the silver atoms move through the crystalline grain to form the latent-image particle, no satisfactory explanation was forthcoming until 1938. In this year Gurney and Mott proposed a theory of latent-image formation which is now generally accepted, and is based upon two specific properties of the silver bromide which forms the emulsion.

The first special property of silver bromide is that it does not form a perfect lattice, but one in which there are a number of free silver ions. These free ions become freed by the effect of temperature on the crystals which causes the lattice to vibrate. If the vibration becomes sufficiently severe an occasional silver ion becomes displaced from its regular position into a new position in which it attempts to fit into a space not quite large enough to accommodate it. The neighbouring parts of the crystal then have to move apart to allow it to fit in. This state of affairs is shown in Fig. 12 which illustrates how a silver ion, once it is in an irregular position can move into corresponding neighbouring positions and so progress through the crystal. The figure also shows how the gap left behind when a silver ion passes into an irregular position can appear to travel as a neighbouring silver ion occupies it, leaving a hole from where it, in its turn, came.

Because of the presence of these mobile ions crystals of silver bromide can conduct an electric current. If two electrodes are attached to the crystal and a voltage is applied, a current will flow. If the temperature is lowered the vibration of the crystal lattice is reduced, the ions cannot travel through it, and the crystal becomes non-conducting.

The second special property of silver bromide crystals is that electrons are released within the crystal when light falls upon it. These electrons originate from the bromide ions. When one of these bromide ions loses an electron by the action of light, the bromide ion is converted into a bromine atom and the electron remains free to move about in the crystal for a considerable time. Thus the crystal can conduct electricity by the movement of electrons, a process which can take place even at low temperatures.

In order to describe the behaviour of electrons in a crystal, the crystal may be compared to a house containing several floors and lift shafts. (Fig. 6). The bromide ions may be thought to live in the basement which is divided into individual sections, each containing one bromide ion, and between which there is no direct communication. There is, however, communication with the next floor by means of a lift. Absorption of light will cause the electron to be lifted on to the next floor which contains passages all across so that the electron is free to move anywhere along that storey.

Thus both the 'constituents' of a silver atom, i.e. the ion and the electron, are capable of moving through a silver bromide crystal when it is illuminated. In this way a substantial particle of metallic silver can be formed by the separate movements of electrons and silver ions. According to the Gurney-Mott scheme, electrons released by light are trapped by the silver sulphide sensitivity particle which in the 'house' analogy must be imagined as a hole into which the electron drops and from which it is unable to free itself. The trapped electrons set up an electrostatic field which attracts silver ions. Thus electrons and silver ions reach the sensitivity speck successively and build up there the latent-image particle (Figs. 6, 8).

The mechanism of development is not so clearly understood as that of the formation of the latent-image particle, but development must be in effect a continuation of the process of latent-image formation in the sense that by the action of the developer further silver is deposited, probably on the latent-image particle.

Various development mechanisms have been proposed and one of the more plausible ones is as follows. The electron microscope picture of a developed emulsion grain shown in Fig. 9 differs considerably from pictures of similar grains taken by ordinary light. The developed grain is seen to consist of a mass of tangled threads. It appears almost as though the developed silver had been squeezed out of the body of the crystal—like toothpaste from its tube. The reason why the external shape of the developed grain is often very similar to that of the original silver bromide is presumably the presence of the surrounding gelatin which confines the developed silver within the space originally occupied by the grain.

The threadlike nature of the developed silver is an essential feature which any mechanism of development will have

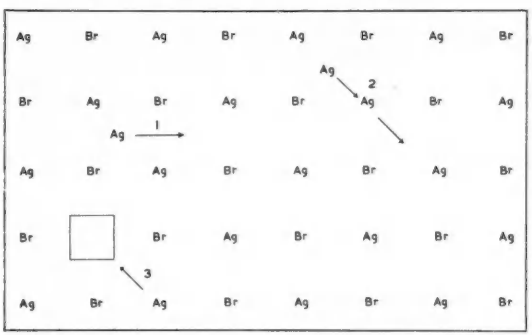


FIG. 12.—The mechanism of ionic conductivity in silver bromide. In 1 a silver ion moves from one irregular position to another, both of which must be imagined to be situated one-half of a lattice distance above or below the paper plane; in 2 a silver ion in a normal position moves into an irregular position and is replaced by another one coming from an irregular position; in 3 a vacant silver ion site is filled by a neighbouring silver ion, thus moving effectively the vacant site to another position.

to explain. The developer solution must be ready to donate electrons to any material capable of accepting them. The photographic grain is surrounded by protective layers of gelatin and of excess bromide ions introduced during manufacture of the emulsion.

The presence of a latent-image particle may be imagined to constitute a break in the protective layers whereby electrons can be passed over to the silver which in consequence becomes negatively charged. From here onwards the process of development is similar to that of the formation of the latent image (Fig. 11).

The negatively charged silver particle attracts free silver ions from the interior of the crystal and in that way further silver atoms, i.e. electrons plus ions, are added to the particle. The surplus bromide ions which remain are taken up by the developer solution. The process continues until the silver bromide grain is entirely converted to silver. Since the new silver formed is always deposited under the latent-image particle, that particle gets pushed out forming the thread shown in the electron microscope picture.

There are many puzzling photographic phenomena which are now explained for the first time by the Gurney-Mott theory. For instance, it is known that the results of an exposure depend not only upon the total amount of light reaching the emulsion but also upon the time and intensity of exposure separately. By this it is meant that the effects produced by (i) a short exposure at a high intensity of illumination, (ii) a longer exposure at lower intensity, or (iii) a very long exposure at very low intensity, are not the same even if the product of time of exposure and intensity of illumination is kept constant. This is known as 'reciprocity failure', and is illustrated in Fig. 10. Photographic materials are most sensitive for a certain time of exposure and lose sensitivity if the time of exposure is longer or shorter.

This effect is explained by the fact that the electronic stage of latent-image formation is rapid, but the ionic stage relatively slow. Thus for short exposure times the ions cannot keep pace with the electrons and latent-image formation is inefficient, the particles being either too small to act as development centres or formed in the interior of the grains where the developer cannot reach.

The instability of very small particles of silver accounts for the loss of sensitivity for long exposure times. Here the particles do not grow sufficiently quickly and tend to become dispersed before they have a chance of reaching a stable size.

In explaining facts such as these, and in stimulating research the Gurney-Mott theory has been most successful. It is an example of the present-day tendency for theoretical physicists to apply themselves to practical industrial problems. The result of this particular venture is a more detailed and satisfying description of the photographic process than had been thought possible only a few years ago.

(Figs. 3, 4, 9, by courtesy of J. H. Tabor and Kodak Ltd.)

New Super X-Ray Machines for Health Service

RESOURCES for the treatment of cancer and other diseases in Britain will be strengthened when five super-voltage X-ray therapy machines of new design become available for use—the first probably early in 1952. These machines will be capable of producing the effect of four million-volt X-rays. Orders for them have been placed by the Ministry of Health, in conjunction with the Department of Health for Scotland.

The actual allocation of the machines, known as Linear Accelerators, has not yet been decided, but one will be centred in London, another in Scotland, and the other three in the provinces.

The Linear Accelerator (the principle of which was described by Professor O. R. Frisch in DISCOVERY, August 1950, p. 263) began as an idea in 1945 when experimental work in this direction was first undertaken by a team at the Telecommunications Research Establishment of the Ministry of Supply at Malvern. They constructed an experimental four-million-volt machine which was first operated in February 1948.

Britain has a lead both in the design of these instruments and in their application to X-ray therapy. The completion of these four-million-volt machines will mark an advance in the equipment available for treating certain types of cases, especially those with deep-seated growths.

The five machines ordered by the Ministry, which will incorporate the latest technical developments, will only be about 5 ft. long. This is remarkably compact for a machine of this high voltage. As a result it will be possible for the machine to be actually swung about inside the hospital treatment room. Mounted on special supports, it can be moved in an arc round the patient in order to adjust the direction of the X-ray beam. By this means it will be made easy to direct the beam at any required angle into the patient for carrying out the complex 'cross-fire' techniques which are used today.

Despite their power, these machines will be as easy to operate as the 200,000-volt X-ray machines commonly used in hospitals. Their mobility and flexibility plus their super-voltage also mean that the number of patients who can be treated in a given time will probably be greater. The overall cost of the five machines, including installation, will probably be between £200,000 and £225,000.

Ten-Million-Volt Research Service

The five Ministry of Health machines will incorporate many features which are being used in a ten-million-volt Linear Accelerator which is being constructed for the use of the Medical Research Council and is now nearly complete. This is a larger and more elaborate machine intended for research in the use of multi-million-volt X-rays. This machine is under test at Manchester, and later it will be installed at the Medical Research Council's Radiotherapeutic Research Unit at Hammersmith Hospital, London.

Joseph Henry—America's Faraday

J. G. CROWTHER

THE history of science in the United States of America offers many profound problems. Their solution will throw light on the causes of scientific progress, and how science should be ordered so that it progresses with the greatest speed. So far, scientific activity has been largely empirical. Institutions have been founded whose origins are as yet very little understood. One of the functions of research in the history of science is to create a conscious understanding of the springs of scientific advance, so that a rational theory of the organisation of science can be worked out.

Such a theory will not be coarse and mechanical, but will be as subtle as human life. Among the many tasks that have to be undertaken is the analysis of the lives and achievements of scientists. The man is a unity in which innumerable aspects of science come together, so the biographical study of the scientist is one of the most illuminating ways of discovering the links between the individual scientist and his scientific colleagues, between the scientist and the society in which he lives, his dependence on resources, on the degree of evolution of apparatus, and a hundred other things.

First, there must be the collection of the facts. Even this cannot be done without historical hypotheses, for the author must have some criteria for selection, and he can do this only by the guidance of theoretical principle. The historian of science consciously develops his guiding theory, which helps him in the collection of fact, and the new facts so obtained enable him to improve his theory, in a dialectical fashion.

We are indebted to Mr. Thomas Coulson of Philadelphia for the new biography of *Joseph Henry*,* which is the most complete that has yet appeared. It contains a valuable extension of accessible information on a very significant nineteenth century American scientist.

Joseph Henry was strong in originality, character and constitution. He was, in his complete range of capacities, one of the most influential scientists in history, and yet he was detached from his time, being untouched by the hysteria in contemporary American life. How did this strong man arise, and persist unaffected and undeflected by the turbulent America of Andrew Jackson, the Frontier, the Gold Rush, the Civil War, the Stock Exchange, to become the parent of the world-organisation of scientific knowledge and scientific bibliography? How did the son of a labourer in a country town in then remote America succeed in making fundamental electrical discoveries before he was thirty years old?

A clue to the many astonishing features of his life is that he was born in the last years of the eighteenth century, in 1797. His steady rational attitude derived from that century. He was of Scottish descent, and was born in Albany, the capital town of New York State. He grew up in an administrative centre, dominated by landlords, with General van Rensselaer at their head, while America was still an agricultural country.

Albany had much of the atmosphere of an early nineteenth-century English county town. There were good doctors and professional men, a good theatre, and a good school, the Albany Academy. Henry's mind was formed in this squirearchical and not uncultured society.

Owing to the poverty and illness of his father, he had to start work at the age of ten, as a boy in a store. In spite of his hard life, he grew into a tall, handsome, pleasant youth, with rather dreamy manners. He had acquired from his mother good looks and refinement, and a characteristic type of careful and modest nonconformist outlook, indifferent to wealth, passed down from his Scottish ancestors.

Yet with this origin, his first passion was the stage. At about the age of fifteen he spent much time in the Albany theatre, probably helping behind the scenes, and training himself as an actor. The director was John Bernard, a talented English comedian, who formed a permanent company of capable players, and wrote several books on the early American stage.

Henry acquired an easy and agreeable manner of public speaking through his theatrical experience, which afterwards aided him as a lecturer.

He seemed to be set for the stage. And then one day, when he was sixteen years old, he had to stay indoors with some minor ailment. One of his mother's lodgers lent him a book to pass the hours. This was one of the conversational books on science, popular in their day. It fired his scientific intellect, and revealed to him his real interest, the explanation of natural phenomena. He at once became acutely conscious of his lack of education, and began to attend evening classes in geometry and mechanics at the Albany Academy. He took lessons in grammar, and soon became so proficient that he was able to pay for his Academy instruction by teaching grammar in outlying districts. Then he was appointed a teacher at a salary of eight dollars a month.

He taught and studied for about sixteen hours a day, without feeling fatigued, and presently passed his examinations preliminary to the study of the calculus.

The local magnate, General van Rensselaer, was looking for a tutor for his children. The post involved only three hours' work a day; Henry was recommended, and held the post for two years, using his ample leisure for further studies.

In this feudal atmosphere, the wild American pioneering life flowed past Henry to the West, leaving him untouched. As the profession of scientist was virtually non-existent, Henry began to study medicine, in order to qualify for a livelihood with scientific interests. While studying, he began to assist in the preparation of chemical experiments at the Academy.

As in the cities and county towns of Europe at that time, public science lectures and demonstrations were a popular form of entertainment and instruction. They appealed to intelligent workmen and the educated professional classes and gentry, in a period when there was very little organised amusement and higher education. In England, classical examples were Humphry Davy's

* *Joseph Henry, His Life and Work*, by Thomas Coulson, Princeton University Press, $5.

lectures at the Bristol Pneumatic Institution and the Royal Institution.

Most of the lectures at these institutions were given by dilettanti, pedagogues or local doctors with scientific hobbies, and a youth who could help to prepare the apparatus was very useful. The laboratory assistant was in fact a professional, compared with the usual lecturers, who were essentially amateurs. This position of assistant is one of the sources of the modern scientific profession. It was in fact the way by which Davy, Faraday, Henry, and many others became professional scientists and created the new modern scientific profession. It was a very strenuous way of becoming a scientist, as we know from the lives of these men, but for the talented individual it was a good one. A gifted youth of working-class origin found himself in the closest personal collaboration with educated professional men and gentry who were enthusiastic amateurs of science. Such a society could be very much more fundamentally educative and encouraging to the individual than the best routine instruction in university classes.

Joseph Henry

The situation not only enabled the young man to learn from his enthusiastic employers, who often regarded him more as a collaborator and friend than a servant, it also gave him the opportunity of making his own demonstrations to an intelligent audience, and receiving public applause for meritorious performance. All of these things are of great importance for the proper development of a man of talent, and have superiorities over the university system of examinations and fellowships, which is narrower and more stereotyped.

The drawback of this method of producing scientists is that it can produce only a very few. The conditions which produced Davy, Faraday and Henry were wonderfully good, but they have only a limited significance for the problem of producing the large number of scientists that are needed today.

Henry gave his first public scientific demonstration in 1824 when he was twenty-six years old. He showed that the temperature of a jet of escaping steam diminished as the temperature and pressure in the boiler increased. There was, of course, nothing new in this demonstration of the effect of adiabatic expansion. It was the kind of experiment that entertained the intelligent non-scientific spectator.

Henry earned a few more dollars at this time as tutor to Henry James, who became the father of the famous brothers Henry and William James.

After an interlude of open-air work as a government surveyor for a new road, he was appointed, in 1826, professor of mathematics and natural philosophy in the Albany Academy. While preparing for the chair, he visited New York, and saw an example of the electromagnet, newly invented by William Sturgeon. He was deeply impressed by it, and immediately made a model of improved design. This led to the publication of his first original paper in 1827, which opens with the observation that "The subject of electro-magnetism, although one of the most interesting branches of human knowledge and presenting at this time the most fruitful field of discovery, is perhaps less generally understood in this country than almost any other department of natural science."

He set out to make electromagnetic apparatus which would give the biggest effects with the minimum amount of electricity. Sturgeon's magnet consisted of a naked wire wound round an iron core covered with insulating material. The coil consisted of a single layer, and the wires were wound at an angle of thirty degrees, so that they did not touch.

Henry had studied Ampère's work, and knew that the coils should be at right angles to the axis of the iron core in order to produce their maximum magnetising effect. He therefore decided to insulate the wire, and wind it closely in coils of many layers, obtaining thereby much more powerful electromagnets. He investigated different ways of winding. A magnet with a single coil of many turns he called an 'intensity' magnet, while one with several coils each of a few turns he called a 'quantity' magnet. He had begun the elucidation of the properties of series and parallel windings.

He found that magnets of the two types should be used respectively in 'intensity' and 'quantity' circuits, i.e. in series and parallel circuits. He had arrived at the notion of matching impedances for maximum power transfer, and had discovered one of the principles which is basic to the operation of the electromagnetic telegraph.

Hearing that experimenters in Europe were publishing results with which he was already acquainted, he hastily wrote a paper summarising his work. This was published in April 1831.

He had begun to clarify the concepts of electromagnetic action which underlies electrical engineering, before current or potential had been defined, and seven years before he heard of Ohm's law. If he had given his quantitative electrical measurements a little mathematical analysis, his already great contribution would have been greater still.

He applied his more clearly apprehended electromagnetic principles to the design of the super-magnet of the day. It weighed 21 lb. and was capable of lifting thirty-five times its own weight. It was relatively as famous in its day as Lawrence's cyclotron is in ours, and brought Henry an international reputation.

The First Telegraph

He demonstrated in 1831 the first electromagnetic telegraph, with nearly a mile of wire. The receiving end was connected to an electromagnet, in front of which was a permanent magnet which could swing on a pivot. When the signal came, the electromagnet attracted the permanent magnet, which swung and thereby struck a bell.

Henry invented the electromagnetic relay about 1835. This consisted of a long-distance circuit containing a series-wound electromagnet and series battery. The

series-wound magnet operated a switch in a circuit containing a parallel-wound electromagnet capable of lifting great weights. He communicated this invention, which is essential for long-distance telegraphy and telephony, to Wheatstone in 1837.

In 1831, Henry published his invention of an electromagnetic engine. This consisted of a horizontal bar electromagnet kept in oscillation by reversals of current through it, caused automatically by the movement of the bar magnet itself.

He wrote a letter to Professor Cleaveland on November 6, 1831, saying that he was constructing a large horseshoe magnet weighing 101 lb., and twice as big as any other in existence, for "some contemplated experiments in the identity of electricity and magnetism". It seems probable that Henry had suspected the existence of electromagnetic induction, and had intended to take advantage of the properties of the electromagnet in order to multiply the size of the phenomenon and thus prove it experimentally.

If this is so, he may have discovered electromagnetic induction before Faraday. There is no question, however, that Faraday published the discovery first, and in a marvellously clear and comprehensive way.

Discovery of Electromagnetic Self-Induction

Henry has the undisputed honour of the discovery of electromagnetic self-induction. In 1832 he published an account of the difference in behaviour when the poles of a battery are joined by a short and a long wire. When the short-wire circuit was broken, no spark was seen, but when the long-wire circuit was broken, a big spark appeared, and if the wire was coiled in a helix, it appeared still bigger. He attributed the effect to the 'reaction on itself' of the charge of electricity in the long wire. Faraday independently discovered self-induction, and published his account in 1834, two years later. The unit of inductance was named after Henry at the International Congress of Electricians held in Chicago in 1893.

Henry was a professor at Albany for six years. In that period, his only uninterrupted time for research was in the annual vacation of one month in August. The rooms of the Academy were needed for teaching, and he could not have his apparatus set up, except in a small basement. His means were very slender, and it is surprising that he was able to obtain such large quantities of copper wire for his big magnets. These were probably given to him by well-to-do amateurs.

His brilliantly original work, done under difficult though not fundamentally discouraging conditions, had brought him fame. In 1832 he was invited to become professor of natural philosophy at Princeton. Here, as has been mentioned, he invented in 1835 the electromagnetic relay. In the same year, he published the principle of non-inductive windings, in which the wire of a coil is doubled on itself, so that the effect of self-induction is eliminated.

He extended the investigation on self-induction, showing how induced currents of the third, fourth and fifth orders could be demonstrated.

The principle of the transformer had been used both by Faraday and himself, but in 1838 he published a clear account of how a transformer enables an 'intensity' current to induce a 'quantity' current, and vice versa.

He discovered too, independently of Faraday, that conductors "are found to screen the inducing action, and this screening effect is shown, by the detail of a variety of experiments, to be the result of the neutralising of a current induced in the interposed body", and he pointed out that such eddy currents had an important bearing on the improvement of electrical machinery.

He saw that the shock given by an electric eel through the water must be due to a secondary current, and he made a model electric fish which would give shocks when touched in the water.

Henry proceeded from the observation of the momentary secondary current, produced at the breaking of a circuit, to the idea that the discharge of a Leyden jar ought to exhibit similar effects. So he was led to investigate oscillatory discharges. Following Savary, he discharged a Leyden jar through a spiral, in which he placed steel needles of various sizes. He found that with fine needles he could reverse the polarity of the magnetisation by increasing the quantity, without changing the direction, of electricity in the discharge. He concluded that the discharge consisted of a "principal discharge in one direction and then several reflex actions backward and forward, each more feeble than the preceding, until equilibrium is obtained." This discovery, published in 1842, was mentioned by Helmholtz in his *Erhaltung der Kraft* in 1847, and explained mathematically, on the basis of the conservation of energy, by William Thomson in 1853.

In the same paper of 1842, Henry showed that magnetised needles in coils detect oscillatory discharges produced by electrostatic machines at distances of many feet through intervening walls.

He noted that a single spark was able to disturb the 'electricity of space' through a large volume, and he compared the effect with the diffusion of light. Thus, in 1842, he was approaching the electromagnetic theory of light, four years before Faraday gave his famous lecture in 1846 on "Ray Vibrations".

One of his students made a note in 1844 that Henry supposed "that electricity pervades all space", and that the fact that each spark made in the College Hall by the electrical machine could be detected inductively at a distance of half a mile was "no more improbable than that light from a candle (probably another kind of wave or vibration of the same medium) should produce a sensible effect on the eye at the same distance."

Henry used his magnetised needles to detect and record lightning flashes up to distances of twenty miles. He had in fact invented the magnetic radio detector, rediscovered more than fifty years later by the student Rutherford in New Zealand, and was half-consciously experimenting with radio waves.

Organiser of Science

The organisation of research in America was not sufficiently developed to enable scientists to work out Henry's profound experiments. There was virtually no one with whom he could discuss his discoveries critically, and Princeton, like the other American universities, had not reached a stage where he could be assisted by a team of research students. If Henry had lived in Europe, he might

have advanced the date of the discovery of radio waves by a generation.

In 1845, he left Princeton, and his great period of original investigation ended. He began another career, of equal distinction, as an organiser of science. He had been called to be the first Secretary of the Smithsonian Institution.

The eccentric English nobleman, James Smithson, an illegitimate son of the Duke of Northumberland, and a descendant on his mother's side of Henry VII, had left his fortune of £105,960 to the United States for the foundation of an institution for "the increase and diffusion of knowledge". Smithson had never enjoyed the place in society to which he felt he was entitled, owing to his illegitimacy. He wrote in his will that "on my father's side I am a Northumberland, and on my mother's side I am related to kings, but this avails me not." By founding a great scientific institution . . . "My name shall live in the memory of man when that of the Northumberlands and the Percys are extinct and forgotten."

Though these titles are not yet extinct, Smithson's name is now more widely known than theirs.

Foundation of the Smithsonian Institution

As first Secretary, Henry found himself in Washington, a raw city in 1846. At the age of forty-nine, he left the academic quiet of Princeton, and had to battle with politicians who tried to secure cuts from the Smithson fortune. Members of the Board of the Smithsonian advocated their own schemes, whether in accordance with Smithson's aims, or not. Henry was forced to accept some of these, but resolutely fought for the spending of income on creative work, such as research, and the distribution of scientific information and literature.

He was intensely opposed to the fantastic design of building chosen by the Board. But by absolute incorruptibility, extreme personal economy, and inflexible perseverance, he managed to guide the Smithsonian into the correct path, and hold it there steadily for thirty-three years.

In the period before the Civil War he was friendly with Jefferson Davis, and at first he was prejudiced against Abraham Lincoln. He was not liberal in his attitude towards the negroes. But when the war started, he was entirely loyal to the North. He had to discuss scientific business with Lincoln, and began to appreciate his intelligence.

Henry decided that two important ways of diffusing knowledge were the publication of original memoirs, and the reprints of important papers and reports for wide circulation. He accordingly instituted the "Smithsonian Contributions to Knowledge", and the "Smithsonian Miscellaneous Collections". He issued an annual Report, containing a review of recent advances in sciences, which had an average circulation of 15,500, and reached remote corners of the world.

He developed a system of exchanges of scientific books and papers which became world-wide, and which after thirty years had grown to the annual handling and dispatch of 99,000 lb. of literature.

In 1870 he was invited to give evidence to a Royal Commission in London on Scientific Education. He said in his evidence that "the great object is to facilitate in every way the promotion of science, and especially the fostering of original research, and enlarging the bounds of human thought. It is a matter of surprise that the idea is not more generally understood by statesmen and legislators, that modern civilisation depends upon science, including the knowledge of the forces of nature, and the modes in which they become the aids of man."

He proposed in his first Report that the Smithsonian should establish an extensive system of meteorological reports. This led to his system of Storm Warnings, and the founding of the U.S. Weather Bureau.

During the first twenty years of its existence, the Smithsonian provided the records of the U.S. surveys of the vast lands being settled in the West. This interest in exploration extended to Arctic expeditions. Collections of biological and ethnological materials were started, which became the nuclei of national collections.

He suggested in his Report of 1851 that "one of the most important means of facilitating the use of libraries is well-digested indexes of subjects". This was necessary for all those "desirous of enlarging the bounds of human knowledge". He recommended his great plan for indexing scientific literature to the British Association in 1854, and this led to the founding of the Royal Society's Catalogue of Scientific Papers, the first volume of which appeared in 1863.

The Application of His Discoveries

As one of the founders of electromagnetism, and the leading electrical physicist in America, Henry was consulted by many of the inventors who were so characteristic of the nineteenth-century United States. Morse came to him for advice in the development of the telegraph, and from motives of megalomania subsequently tried to deny his indebtedness. Intense legal forces were unleashed against Henry, which he withstood magnificently.

Graham Bell was also deeply indebted to him, but unlike Morse, he very generously acknowledged his debt.

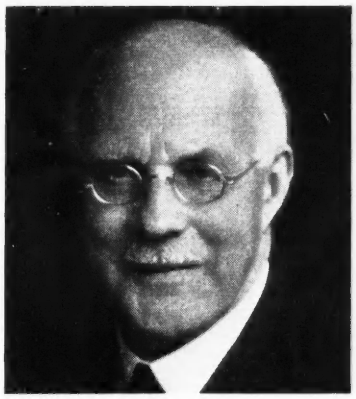
If Henry had patented the telegraph, the relay, the non-inductive windings, and his other inventions he would have drawn an immense fortune from royalties. But he had always insisted on free publication of pure discovery. He refused even to accept consulting fees, and his income from the Smithsonian was never more than 4500 dollars a year, with the use of a seven-roomed house. He had made no provision for his dependents, and in his last year a fund of 40,000 dollars was collected to provide for them.

As the years pass by, Henry's stature as a discoverer, and as a statesman of science, increases. His devotion to fundamental research and to the planning of science, and his disinterestedness, show him as a balanced personality and a man of the future.

His achievement was all the more remarkable because he lived in a period of febrile social excitement, when men were going mad with gambling on the riches of a newly settled continent, and on the applications of his own scientific discoveries. While his fellow Americans were pioneering the West, he was pioneering scientific civilisation in Washington.

British Association at Birmingham

JUDGED by the size of the membership and by the number of people who actually attended the sessions, this year's meeting of the British Association, which opened at Birmingham on August 30, and ended on September 6, was exceptionally successful. The membership amounted to 3,744, a record for B.A. meetings held in the provinces this century. Only three times in the history of the B.A. has this figure been exceeded—in 1914 when the B.A. met in Australia, in 1931 the bicentenary meeting in London, and in 1881, the year of the Jubilee meeting in Manchester.



Sir Harold Hartley

IN a short speech to the press conference held at the end of the meeting, the president, Sir Harold Hartley, said the meeting had been an outstanding success—apart from one fault, the inaudibility of some of the lecturers. This view has been challenged by Chapman Pincher, science editor of the *Daily Express*. His criticisms were in line with the opinions we heard expressed on all sides, by scientists as well as science writers who were present throughout the conference. For the science writers who attended there was little real 'news' in the conference; this is due to the fact that the British Association is no longer regarded by scientists as the appropriate place at which to announce discoveries. Many of the papers were of too limited interest; one result was that there was relatively little traffic between the sections, which is a pity, as a British Association meeting is one of the few occasions where a chemist, for instance, has the chance to go and learn about advances made in other branches of science that impinge on his own particular field of specialisation. British Association papers are becoming less intelligible to all except the extreme specialist. The lay members whom the B.A. has always sought to attract, were comparatively poorly served; the growing tendency is for lay members to ignore the main sessions and to concentrate on the few special popular lectures that are arranged. (There were three such lectures this year.)

This general trend is understandable, but many feel that it needs to be reversed. The British Association needs to reconsider what its functions are; if it does so, it will be bound to conclude that it does not exist to duplicate the functions of the specialist scientific societies. We hope that there will be more sessions with a wide general interest at the Edinburgh meeting, to be held next year from August 8 to August 15. It is being held earlier than usual so that those who wish to stay on for the Edinburgh Festival (which begins the following Sunday) will be able to do so.

THE PRESIDENT'S ADDRESS

THEME of the presidential address by Sir Harold Hartley, F.R.S., was "Man's Use of Energy", and dealt with the world's power resources in a way that made it a natural sequence to last year's presidential address by Sir John Russell on the world's food supplies. The opening part of his speech was devoted to a historical survey of the development of steam and electric power, and the birth of the internal combustion engine. He then spoke of the social effects that followed the making available of such sources of power as the internal combustion engine.

Sir Harold then posed the question: What measure have we of the significance of energy to man today? "In the nineteen-thirties the correlation between the average real income and the consumption of energy per head in different countries was so close, with a few exceptions, that it showed how essential supplies of energy are if a reasonable standard of life is to be maintained. Energy is the multiplier of human effort. But its effects are not found in comfort and productivity alone. The rapid interchange of persons and ideas has brought the world together into a much more closely integrated unit. It has quickened the senses and the nerve fibres of nations and given them a new awareness of events, a new world consciousness which in due time must show their inescapable community of interests.

"And with all these new uses of energy and its growing population, the world's demands are rising daily. How can they be met? Sir John Russell's problem last year of the world's demand for food was simple compared with mine. There is a limit to the capacity of the human stomach, but none to man's appetite for energy, and he finds new uses for it every day."

World Consumption and World Resources of Energy

The world's consumption of every kind of energy today, food for men and beasts, heat, light and power, needs a gross yearly intake equivalent to four thousand million tons of coal. On a thermal basis this demand is met by food from agriculture 21%, by coal and lignite 41%, by wood 6%, by oil 24·5%, by natural gas 6·5%, by hydro-electricity 1%. So that about 30% comes from the current revenue of plant and animal growth and water power and the remainder from the capital resources of coal and oil. Leaving aside the work equivalent of human and animal labour, and taking into account the efficiency with which the other energy sources are applied by man, their useful contributions today are roughly solid fuel 56%, liquid and gaseous fuel 37%, water power 7%.

Sir Harold said that world reserves of coal are ample for centuries; with oil and natural gas there is no reason to fear a shortage for decades, and before then synthetic oil from coal and oil from shale will provide substitutes. If the world's reserves of water power were all to be developed, their output would equal the total inanimate energy man is using today. But these reserves are scattered, and many lie in distant regions far from the crowded areas of the world—in the Belgian Congo, French Equatorial Africa, the Cameroons and South America. And like coal and oil there is a most unequal distribution of resources between nations. The countries north of latitude 20° contain 94% of the world's coal reserves and 83% of the oil reserves, while those to the south contain two-thirds of the world's water power potential. So that the pattern of development of countries, which must be related to their energy resources, will inevitably be very different.

These inequalities are reflected in consumption today. At one end of the scale the United States use yearly the equivalent of 9 tons of coal per head, while at the other India and China are using less than one-fifth of a ton per head. The figure for Britain is a little over 4 tons of which one-third provides domestic needs of heat, warmth and food, leaving nearly 3 tons for transport and industry.

Sir Harold focused attention upon the very interesting fact that in Britain until 1938 the total fuel consumption was almost

unchanged for a quarter of a century, during which time the population had increased by 10% and the use of heat and power in industry, had been extended. The extra energy required came from the same amount of fuel by increased efficiency of use. Great improvements in efficiency could still be made.

Sir Harold then turned to future developments, some of which can bring benefits almost immediately. He mentioned the gas turbine; several land and marine types are now being developed to use gaseous, liquid or solid fuels. It has the advantage of compactness, it can be used where no cooling water is available, and it is specially suitable for burning by-product or waste gases. Underground gasification of coal is being tried in several countries and if successful the gas turbine may possibly be the best means of utilising the gas obtained. In Britain much depends on the success of the gas turbine using coal by one means or another.

In Italy the internal heat of the earth has been used successfully in a geothermal power station on an ever increasing scale for more than thirty years. Difficulties and dangers in drawing steam from great depths and using it have all been overcome. Italian engineers and scientists have set a great example that could be followed wherever thermal springs or volcanic steam are found.

Few advances have been made in using wind power, one of the earliest forms of energy used by man, but now with the progress in aerodynamics, new experiments are being tried which may produce power economically to be fed into a grid system and thus save coal. At favourable sites in Britain it is expected that wind-driven generators weighing about 300 lb. per kW. will produce 4,000 kWh. per kW. per annum.

Sir Harold saw that the transmission of high-voltage D.C. electricity, now already beyond the experimental stage, should make it possible to transmit large blocks of energy economically for perhaps a thousand miles by underground or submarine cable and thus link consuming centres with new and distant sources of hydro-electric power, so rectifying deficiencies arising from the unequal distribution of energy sources over the world.

He spoke of the tantalisingly immense amount of energy reaching the earth by solar radiation and the small use we make of it. "Sunshine is so often available at places remote from other energy sources, that we surely have a duty to posterity to pursue long-term researches in this field while we are living on reserves," he said.

Nuclear energy means a concentrated source of energy—nuclear 'fuel' is several millions more concentrated than coal. Sir Harold acknowledged that developments here could make energy available to remote places of the earth where it is needed, but he expressed the view that with the world's need of energy, it would be a tragedy if the fear of competition from nuclear piles were to delay in any way the immediate development of the more conventional and better understood sources of energy.

"Now, as I near the end of my address, I wonder, have I claimed too much for progress—progress, that missing word among the Greeks? Have we replaced the Golden Ages by an Age of Steel? Has man's use of energy brought happiness or not?" asked Sir Harold. "There is no yardstick that can tell us, in Priestley's phrase, whether the 'greatest happiness of the greatest number' has increased. We see the contrast of man's swift advance in understanding Nature and the troubles of the world today. Is the myth of Daedalus for ever true? Sir Arthur Keith ends his 'New Theory of Human Evolution' with the words 'In the clash and turmoil of this modern world we are hearing the creaking wheels of the machinery of evolution.' Is it inevitable, as he concludes, that in this great revolution through which we are passing the old primitive enmity of nations, the urge to self-sufficiency will grow stronger? What ground is there for hope?

"I turn to Carnot's essay for the answer. In 1824 he wrote 'Navigation due to the steamship has in a measure drawn together the most distant nations. It tends to unite the peoples of the earth as if they lived in the same country.' His prescient eye had seen that energy would bring the world together. We see today the stirring of a new world consciousness that must in time bear fruit, a new awareness of the load the modern Atlas has to bear, the problems we must face: the growing strain of increasing population, the malnutrition and endemic sickness of perhaps half the world, the inequalities between the more forward and the backward peoples, the gradual depletion of resources and their unequal distribution and, by no means least, the human problem of changing the way of life and outlook of many millions. The hope lies in man's new understanding of Nature's processes, in his more efficient use of her resources and in the growing recognition of the dependence of one nation on another. On man's wise use of energy depends so much the future of this troubled world."

Atomic Power: Sir John Cockcroft's Cautious View

ONE session of the Physics Section was devoted to nuclear reactors, the use of these piles for experimental purposes, and the industrial possibilities of radio-active isotopes and nuclear power. Sir John Cockcroft, director of Britain's Atomic Energy Research Establishment, was extremely cautious when he spoke of the prospects for piles as generators of power on a commercial scale. He said it seems likely that the first pilot power pile will be operating within 5 years, and until we have experience in the operation of that pile, worthwhile predictions on the future of nuclear power cannot be made. "It is obvious," he said "that nuclear power is in a very early development stage, and that there are many formidable problems to be solved before it can be reached on any huge scale."

Referring to Harwell's second pile, known as BEPO, he said this was designed to develop the equivalent of 6000 kilowatts of heat-energy. Advances in metallurgical technique (as for instance in connection with the problem of finding a metal for sheathing the uranium rods to control radioactive leakage) make it possible to step up BEPO to about 10,000 kilowatts. Sir John foresaw the development of a BEPO-type pile to operate at still higher temperatures, providing that a metal capable of withstanding higher temperatures than aluminium, and which would not absorb too many neutrons, can be found, for sheathing the rods of uranium 'fuel'. Such nuclear furnaces may be able to operate for 10–30 years without 'refuelling'.

Sir John Cockcroft stressed that at present only very rough estimates of the possible cost of nuclear power can be made; these estimates suggest that nuclear power costs will not differ very much from power from coal.

Industrial Uses of Radio-isotopes

A NOVEL use of a radio-isotope was given by Dr. Henry Seligman of Harwell in his paper on 'Industrial Uses of Radioactive Isotopes'. It was devised in connection with the underground gasification experiment now under way on an open-cast site at Newman Spinney, near Sheffield (described in *Discovery*, August 1950), the gamma rays of radioactive cobalt have here been used when it was needed to make an underground connection between two pipelines. Holes were to be put through from different directions in a coal seam, and the scientist wanted to determine the two points in the holes nearest to each other, and to estimate their distance underground. This was done by using a radioactive cobalt source with a window in its lead container. This container was inserted in one hole, and an instrument for detecting gamma radiation in the other hole. The nearest points were so determined, and the distance between them was estimated; it was then possible to place an explosive charge so that it shattered the coal and made the connection that was desired.

Another concrete example of a radio-isotope being used in connection with coal mining was mentioned. A lake holding a million gallons of water was suspected of leaking into a coal pit; it was necessary to decide whether the lake should be pumped dry, but the first thing to decide was whether direct leakage into the coal pit was occurring. With a kilogram of salt containing radioactive sodium added to the water of the lake, leakage could be proved or disproved more easily than with any dye that can be used for this purpose.

Radioactivity induced in bearings of pumps can be used to settle questions of lubrication. With bad lubrication quantities of metal are worn away, and a method was needed for determining small amounts of iron present in the lubricating oil. In one convenient method that was devised the bearing is rendered radio-active by exposing it to bombardment with neutrons. It then became practicable to detect (and estimate) a tenth of a milligram of iron per litre of lubricating oil; the figure can be improved upon by concentrating the iron debris in the oil.

Dr. Seligman also referred to the use of radioactive substances which emit beta

rays in connection with the control of thickness of materials being rolled in a production process. A prototype instrument depending on this was shown by Harwell at the British Industries Fair in 1949. Several commercial instruments for this purpose are now on the market and are already widely used in interest.

Radiography with Gamma Rays

GAMMA rays are today being used like X-rays for the non-destructive testing of metal objects. A paper by Mr. W. S. Eastwood described the work being done at Harwell to discover the most suitable radioactive isotopes for use in this 'gamma radiography'. The isotopes under consideration for these purposes have convenient half lives—of a month or two, as compared with the natural emitters, Radon (3–8 days) and Radium (1590 years).

Where a radiograph of an object with a thickness of 2 inches of steel and upwards is required several radio-isotopes can be used; Cobalt 60, Europium 154, Tantalum 182, Antimony 124, and Scandium 46—all these are suitable. For steel thicknesses of ½–2 inches, Iridium 192 is far the best; it is preferable to Selenium 75 and Hafnium 181, though these are quite effective for this purpose.

V-Particles

A PAPER by Professor P. M. S. Blackett, of Manchester University, announced that confirmation has been obtained of the existence of very heavy unstable mesons, known as V-particles because of the shape of their disintegration tracks. He showed cloud chamber photographs of their disintegrations taken both by Carl Anderson at Pasadena and by the British research team at the observatory some nine thousand feet up the Pic du Midi. The pictures showed the same sort of pattern as the two cloud chamber photographs taken in 1946 by Dr. G. D. Rochester and Dr. C. Butler, first suggested the discovery, which seemed to indicate the existence of two new particles, of a mass of around nine hundred electron masses, which were spontaneously unstable. One was neutral and decayed into two charged particles, and the other was positive and decayed into a positive and a neutral.

The view suggested by these two isolated photographs has now been confirmed by 34 more taken at Pasadena, where the masses of the new particles have been estimated to be between 250 and 400 electron masses larger than the sum of the masses of the particles into which they decayed. What was clear was that the products of their disintegration were pi-mesons, which formed so much more familiar a feature of the cosmic radiation. Professor Blackett did not think we were yet able to estimate the lifetime of the V-particles, but Anderson had put it at round about three ten-thousandths of a millionth of a second. While Pasadena has been obtaining the confirmatory results the great magnet providing the field of Professor Blackett's cloud chamber has been transported to the Pic du Midi. The cloud chamber began to work there two months ago and new photographs of V-particle disintegrations are now being obtained once a week.

Dating by Carbon 14

THE dating of biological material that is several thousand years old by means of the radioactive isotope of carbon known as Carbon 14 was described by Mr. J. V. P. Long, of the Radiochemistry Section of the Chemical Research Laboratory, Teddington. Carbon 14 is produced in nature by the impact of neutrons formed by cosmic rays upon the nitrogen in the earth's atmosphere. The amount of radiocarbon has reached an equilibrium in which the rate of production of Carbon 14 atoms is equal to their rate of decay. (The decay takes place by the emission from the atom of a weak beta-particle which may be detected by means of a Geiger counter.)

Living plants absorb carbon dioxide during life and cease to do so upon death. The Carbon 14 absorbed during the life period is not renewed and slowly decays with a half life of about 5000 years. This means that the radioactivity per gram of carbon derived from material 5000 years old will be half that derived from carbon from material alive today. By making use of these facts and by measuring the very small radioactivity of carbon obtained from old material Professor Libby and his co-workers have been able to determine the age of a number of specimens. One of the most interesting of these is the determination carried out on pieces of a ring of a redwood tree 2928 years old (*Sequoia*) which gave a result of 3005 years. This demonstrates the validity of this method of dating, but also the fact that no exchange had taken place during subsequent growth of the tree.

The Wegener Theory

THE pros and cons of the Wegener Theory —according to which the continents used to be closely packed together and drifted apart in the course of geological time to take up their present positions—were discussed by a joint session of the biologists, geologists and geographers. The pattern of discussion was familiar: the biologists favoured the theory which offers an explanation of difficult points arising in the study of the distribution of plants and animals (as, for instance, the striking similarities between the fauna of S. Africa and S. America) and the geologists bringing forward data that emphatically contradicts Wegener's hypothesis.

At the end of the discussion the chairman, Dr. W. B. Turrill, invited the scientists to express their opinion for or against the theory by voting—a show of hands. The vote was not counted, but it was virtually a dead-heat.

Misguided Faith in Insecticides

A STRONG warning about the dangers of putting too much faith in the efficacy of insecticides as a means of insect pest control was given by Dr. V. B. Wigglesworth, F.R.S., in his presidential address to the Zoology Section on "The Science and Practice of Entomology". He uttered this warning, after asking the rhetorical question, "Is not the entomologist outmoded by the discoveries of the organic chemist in the realm of insecticides". After paying a tribute to the Swiss, British, and German chemists who discovered the insecticidal properties of DDT, Gammexane and organo-phosphorus insecticides, he pointed out that it creates a greater impression on the mind to destroy an infestation of insects that can be seen, than by some simple change in practice to prevent any infestation from developing. "Effective methods are known for preventing the breeding of house flies, methods based on simple biological principles. But," said Dr. Wigglesworth, "I know of at least one institution which could not be interested in such methods but adopted instead the practice of spraying the walls with DDT. The house flies in that institution are now among the most DDT-resistant in the world."

He went on to say that it becomes increasingly obvious that the use of more insecticides is creating problems as fast as it solves them. In orchards, for example, an ever increasing number and variety of insecticidal washes have to be used to secure clean fruit; thus early in the century two or three sprays applied with hand pumps sufficed to give good fruit, but today with greatly improved spraying equipment and far more potent chemicals six or even ten applications are needed to produce crops reasonably free of insect damage. In the orchards of Nova Scotia the familiar mussel scale *Lepidosaphes* has been known for more than fifty years; but only in the past fifteen years has it become a pest—and then only in those orchards which have been most thoroughly treated with lime sulphur for the control of apple scab. That is because the Chalcid *Aphelinus mytilaspidis* and the predacious mite *Hemisarcoptes malus* which normally hold the scale in check are killed by the sulphur. The same has happened with DDT which has produced great outbreaks of the Woolly Aphis, the Red Spider Mite and other pests. "We can, as A. D. Pickett points out, probably control any specific pest with which we have to deal—but the problem of pests in general gets worse. New machinery and new chemicals are developed, and we are carried from crisis to crisis, always hoping that the newest chemical or the newest technique will provide the final answer."

The Biological Approach

"Where is this process going to end? Already the number of washes recommended in some parts of the world is reaching the limit of what it is economic to apply. We do not know what the end is going to be. Not even the most enthusiastic entomologist believes that chemical control in orchards can be dispensed with. What we need is more control of the chemists. We need more biological research to see just exactly what effect the chemical applications are having upon the insect populations as a whole," said Dr. Wigglesworth. "*By all means let us use insecticides when we can do no better. But we should regard them as an admission of failure, to be replaced by the more subtle and more remunerative methods of biology as soon as these can be worked out.*"

Dr. Wigglesworth then gave some instances of the success of the biological approach to such problems. In the northern territories of West Africa it has been proved that sleeping sickness can be reduced by 98 % simply by removing from the riverine habitat of *Glossina palpalis* and *G. tachinoides* (two species of tsetse fly carrying trypanosome diseases), a few species of evergreen trees and shrubs, and so changing the environment in the dry season retreats of these flies just enough to render them untenable. In South Africa the Pine Thrips (*Heliothrips*) has been controlled simply by thinning out the trees to give them more light and air. In Britain a good, if crude, example of similar "applied ecology" is the selection of good sites for growing virus-free seed potatoes in N. Wales and S. Devon. (The virus diseases of potatoes in this country are carried mainly by Aphids, particularly by *Myzus persicae*. Seed potatoes largely free from virus can be raised if conditions are unfavourable for the migration of winged Aphids to the potato crop. These Aphids overwinter in numbers in localities where crucifers are grown on a large scale. High atmospheric humidity and exposure to the prevailing westerly winds inhibit migration. The areas mentioned provide these desirable conditions.)

Dr. Wigglesworth urged that applied entomology needs to be regarded as research. He expressed strong disagreement with those who urge a halt to research on the grounds that what is most needed is the application of existing knowledge. "I have no wish to disparage the very great importance of the dissemination of knowledge, but anyone with the smallest acquaintance with practical problems knows that at every point practice is held up by lack of knowledge. The sense of frustration often comes from the fact that the applied entomologist who sees what we need to discover is so occupied with petty tasks that he has not the chance to fill the gap."

As an example of research workers too occupied with matters other than research matters, he cited those who do research on classification at the National History Museum. He suggested that in the interests of this research the staff should be protected from trivial incursions by the existence of a screen of public relations officers who would provide the connecting link between the general public and the specialist—to the advantage of both.

Selective Insecticides

THE special advantage of selective insecticides that can kill insect pests without destroying beneficial insects which prey on the pest was brought home to the mixed audience of chemists and biologists who listened to the paper by Dr. W. E. Ripper, managing director of Pest Control Ltd., the well-known firm of agricultural spraying contractors.

Dr. Ripper gave an account of the development of one of the organophosphorus compounds which the plant apparently absorbs into its system, becoming toxic to many aphids and to the red spider, but remaining harmless to the insects which prey on them, and to bees. He gave experimental data to show that toxicity persisted after spraying from some three weeks in the summer when the plant was growing fast up to four months if applied in the late autumn. If six weeks free of spraying was allowed before harvesting, he said, a toxic residue in the crop was avoided.

Other advantages mentioned by Dr. Ripper were that the substance did not require the considerable volume of water needed for the spraying of most insecticides. Seed could be soaked in a solution of the substance and immunity was transmitted to the young plant. He also claimed that it would help to control plant virus diseases such as rosette in ground-nuts, and swollen shoot in coco plant, which are transmitted by insects.

Dr. Ripper said there were a number of ways of showing that a plant spread the substance through its system. He gave a demonstration with a sample of the insecticide in which radioactive phosphorus had been incorporated. A number of cabbage plants to which the insecticide had been applied three days before to some of the lower leaves, gave an audible reaction on a Geiger counter when this instrument was passed over any part of the plant; the cabbage plants had become radioactive both above and below the points of application.

The chemical name of the substance is bis (*bis dimethylamino phosphorus*) anhydride, but it is known commercially as Pestox 3. It is likely that official recognition will soon be given to the name Schradan, after Dr. G. Schrader, who first discovered it in Germany during the war, while working on poison gases for use in warfare. It has an equally long, but different chemical name in America, but it is usually known there as 'Ompa'.

Dr. Ripper said that although the substance was very poisonous they had, by using gas-proof cabs, avoided any case of poisoning although over 6000 acres had been sprayed. His final point was that because the substance was toxic only to pests and not to beneficial insects, it opened up a new field of co-operation with the biologists and entomologists. Their knowledge of predatory insects and parasites could now be applied in conjunction with these systematic insecticides and a joint system of biological and chemical control operated.

Systemic Fungicides

THE possibility of discovering fungicides which can be applied to the soil, and absorbed by crop plants through their roots and thence conveyed to the leaves and other organs, was mooted by Prof. R. L. Wain of Wye College. He has been working with S. H. Crowdy, investigating the properties of chemicals related to the plant hormones and selective weed killers such as 2, 4-D. Promising results have been obtained with 2, 4, 6-trichlorophenoxyacetic acid. Young bean seedlings were grown for two weeks or so with their roots immersed in solutions containing 10 parts per million of this acid; when these seedlings were sprayed with a suspension of the spores of a pathogenic mould (*Botrytis cinerea* or *B. fabii*) they remained considerably more healthy than untreated seedlings did. At the same time the acid slightly checked the growth of the seedlings.

Compounds which failed as systemic fungicides because they broke down in the plant after absorption through the roots have proved active as ordinary 'direct fungicides' applied to the leaves. These are alpha-2-naphthoxy-propionic and the beta-aryloxypropionic acids.

Automatic Control

PROFESSOR A. TUSTIN, in a paper read to the Engineering Section, underlined at the outset the difference between a control mechanism that carries out a predetermined routine of operations and one that operates not a predetermined routine, but one depending on circumstances and devised to bring about a predetermined result.

An example of the first sort is the automatic record-changer on a gramophone. This goes through its slow routine of lifting the record that is on the table and depositing a second one immediately an exaggerated sweep of the pick-up arm is produced. The mechanism can be deliberately set going, even in the midst of a performance, by lifting the pick-up arm and giving it the needed exaggerated sweep. In other words, with the appropriate stimulus the whole sequence of operations is carried out. An example of the second sort is the automatic pilot on an aircraft. The stimulus to set the mechanism in operation is the *error*, the difference, say, between the desired course and the one being attempted by the aircraft. The error actuates the control mechanism and this control mechanism then readjusts the error, keeping it at a negligible level. This is an "error-actuated" or "feed-back" control mechanism. Also, because the error determines the control operation and the control operation affects the error, there is a closed sequence, and thus any such system is also known as a "closed sequence" mechanism. When such control operates on mechanical movements it is also called a "servo" mechanism.

Thus the adjectives, "error actuated", "closed sequence", "feed-back" and "servo" are synonymous so far as the principles involved are concerned.

Control systems of the feed-back type are important over a wide range of activity besides engineering. As an example Professor Tustin illustrated a well-known and intricate economic theory with elementary concepts such as income, production and expenditure, some of them in a closed-sequence linkage. The human neuro-muscular mechanism also includes closed sequences.

The action of putting one's hand down to pick up an object, for instance, includes a gradual and automatic control of speed so that the hand reaches the object with a predetermined speed and a predetermined set for the action of picking up.

Many examples of modern applications of closed-sequence control were given, some in detail. They included the control of a telescope to keep it trained on a moving star, the control of thickness of

steel strip during manufacture, the control of chemical composition in a number of processes, and temperature control in such processes as those of the pasteurisation of milk, distillation of oils, and food storage. Every closed-sequence control system, however, is limited in that a time delay occurs and so the correction fed back is maintained for a short time after its cause has ceased, and thus an error opposite to the original one is caused. If the amplification applied in the intermediate amplifier is high enough, this effect produces an increasing oscillation called "hunting". Much of the improvement of recent years has been in the achievement of greater accuracy of control, i.e., greater amplification to enable response to be made to smaller and smaller errors, without hunting.

Mathematics of Football Pools

DR. B. KUTTNER, lecturer in pure mathematics at Birminghan University, read a paper to the Mathematics Section dealing with the probability rules applicable to football pools. He pointed out that if there are n matches whose results are to be forecast, there are 3^n possible solutions. (That is to say, every match has three possible results, home win, away win, or draw, and so a complete forecast of ten matches to be certain of getting one set of forecasts right would need 3^{10} columns, that is, 58,549). He set himself the problem of finding the smallest number of entries that could be arranged in such a way as to ensure that, whatever the outcome of the matches, one entry at least should have at most one match wrong. He gave a general formula for calculating the least number of entries required to guarantee one entry being all correct except for one match result; this is three to the "nth" divided by $2n$ plus one. He pointed out that it would be necessary also to avoid wastage arising through some of the cases covered by one entry being repetitions of some of those covered by another. When the formula gave an integer this was the number of entries, but when it was not an integer a larger number had to be made—not necessariiy the next largest number. Thus with only three matches the formula gave a figure of 3 and six-sevenths, suggesting four as the number of entries, but this number would not satisfy the criterion of no wastage. Thus, five, not four, entries would be needed. Dr. Kuttner conjectured that the same sort of result would hold when there were more matches. Using this method of argument, he calculated the number of necessary entries for forecasting the results of 13 matches. The formula gave an answer of 59,049 entries, an exact answer, and it is possible to arrange the entries so that there is no overlapping, and hence this number will suffice; that number of entries at a penny an entry would mean investing nearly £250. But if there are 12 matches the formula does not give an integer, the answer being 21,257 and a fraction. Dr. Kuttner conjectured that the next integer, 21,258, would not be enough to satisfy the no wastage criterion, but a slightly higher number would be required.

"Endeavour" Prizes for Science Essays

AT the conclusion of his presidential address, Sir Harold Hartley announced the names of the prize-winners in the scientific essay competition which has been sponsored by *Endeavour*, the I.C.I quarterly journal. First prize of fifty guineas was awarded to 24-year-old W. J. T. Dunstan, Lecturer in Physics at the Northern Polytechnic, London, for an essay on "Phenomena at Low Temperatures". Winner of the second prize (25 guineas) was 22-year-old S. J. Adelstein, a post-graduate researcher of Harvard University, who wrote on "The Biological Significance of Trace Elements". F. J. C. Rossotti, of Merton College, Oxford, who is 23 years old, won the third prize of 10 guineas.

In addition, a special prize of 5 guineas has been awarded to 17-year-old R. D. Cohen, of Clifton College, who sent in an entry of unusual merit for so young a competitor.

The prize-winning essays were selected from 117 entries, a considerably greater response than was anticipated. Most of the essays submitted were review articles and written at a level comparable to such articles published by, say, *Nature* or *Science Progress*. Practically none fell into the 'popular science' class and it is to be hoped that some organisation will fill the gap by offering prizes for good popular science writing.

Was America discovered before Columbus?

A DISCOVERY of America, antedating that of Columbus, by the Portuguese, probably by Ferdinand Dualmo in a voyage from the Azores in 1487, was postulated by Professor A. Davies, of Exeter University, in a paper to the Geography Section. King John of Portugal, knowing of the existence of a land mass across the western route to the spice islands of the East, had, Professor Davies suggested, connived at the Columbian 'discovery' in order to divert Spanish attention to the west while the Portuguese established a monopoly in the spice trades by way of the eastern route round Africa which they had opened up. He drew his evidence from certain navigational peculiarities of Columbus's first voyage and a number of contemporary Portuguese maps, supported by an examination of Columbus's relations with the courts of the two countries and of their struggle for power.

The peculiarities referred to by Professor Davies were Columbus's rigid adherence to a course due west from the Canary Islands. his conviction that he would reach land after travelling 750 leagues against all the cosmographical opinion of the time, his false and shortened recording in his log of the distance travelled, and his false recording on three occasions of the position of North Cuba as 42 degrees North instead of 21 degrees.

These false recordings were not due to ignorance, Professor Davies said, because Columbus showed himself at other times to be a fine navigator. Such false data were not designed to hearten the crew as to the length of the voyage, because navigational data were jointly decided by the master, pilot, and experienced seamen, and in any case, no such attempt was made on the two other boats of his fleet, and with their evidence to hand there could be no deception in Spain.

The falsifications were for purposes of Columbus's own, Professor Davies said, and the clue lay in his visit to King John in Lisbon on his return journey, before continuing to Spain, although the King had issued a warrant for his arrest. Columbus, through his brother, Bartholomew, who was a cartographer employed by King John, already knew of the existence of America, and his false data was to convince the King that he had discovered land not already known to the Portuguese, so that his discoveries and the large claims he had upon Spain, if his voyage were successful, should not be challenged.

Professor Davies showed Portuguese charts made between 1500 and 1507 on which the American coast line from 39 degrees north almost to the southernmost point of South America is marked with quite distinct features. The original discovery he assigned to Ferdinand Dualmo, to whom in 1486 King John had issued a royal charter to discover lands to the west.

Food Plants: Their Influence on Civilisation

THE influence of food plants on social structure was the subject of Dr. Redcliffe N. Salaman's address to the Archæology section. This was mainly concerned with the potato, not unexpectedly as the author has made a special study of that vegetable and of the social repercussions which followed its adoption in various countries as a staple food crop. (Readers will recall that recently Dr. Salaman published an encyclopædic work on this subject, *The History and Social Influence of the Potato*, which was discussed in DISCOVERY, October 1949, Vol. X, page 309, in a long article by J. D. U. Ward).

Though Dr. Salaman concentrated on the potato in his address he said that as rich a harvest awaits the student who investigates the social influence of rice or maize. Research in relation to home-grown cereals like wheat, barley and oats would doubtless prove more difficult. "But so worth while, I am convinced, are such researches, that I look forward to the time in the near future when a greatly enlarged edition of de Candolle's *Origin of Cultivated Plants* will devote most of its attention to the repercussions of the various staple foodstuffs on human social relations. There is surely a great future for research of this nature which, following Fraser Darling's example, may be described as Human Ecology," said Dr. Salaman.

Dr. Salaman summarised the main points of his address in the following words: An easily grown, cheaply produced,

substantially efficient and pleasantly tasting food can, under certain political and economic conditions, together or alone, fatally menace the social well-being of the people who adopt it.

In England the adoption by the workers of a cheap food like the potato, automatically prevented a rise in wages. The price of bread might be almost prohibitive, and that of meat beyond the labourer's means, but it could not be said that the people were starving and incapable of work, so long as they had the potato to fall back on. The effect, therefore, of the potato was to stabilise the standard of life at a lower level than would have prevailed had no such substitute food been available.

In Ireland, the forces which gave the potato its unexampled dominion over the life of the people were political, economic, racial and religious—no mean combination. The political and economic degradation of the Irish people had been intentional, and the use of the potato had made it absolute. So long as the potato was economically the least common denominator of the art of living, it was easy to hold a nation in subjection. But the potato economy did more than depress the standard of living to an irreducible minimum, it went a long way towards shaping the way of life of a whole people. Its influence, both in its industrial and in its communal aspects, can be traced in the structure of even nineteenth century Irish Society.

This unique despotism outlived the political duress which had nurtured it. Not even the complete loss of the crop by blight, and the subsequent famine, were sufficient to open the eyes of the people either in Ireland or England, to the danger of building the economic life of a country on so narrow and treacherous a basis.

The influence of the potato in the Highlands of Scotland after 1745 was another example illustrating the same theme, but in which both political and religious factors—so imminent in Ireland—were absent; but this was another story.

Plants and Man's Supplies of Energy

THERE has been talk of the possibilities of increasing the output of crop plants by stepping up the efficiency with which the plants used solar radiation in photosynthesis. Professor F. G. Gregory, the plant physiologist of the Imperial College of Science and Technology, gave a paper which was a restatement of the salient facts about photosynthesis and a corrective for any false optimism that may exist as to the prospect that higher photosynthetic activity can be achieved.

He said the most important way in which solar energy is used on this earth is by the fixation of carbon by plants, either from the carbon dioxide of the air or from carbonates and bicarbonates in the sea. In order to fix the carbon, a considerable amount of solar energy is needed to support the chemical reactions involved—equivalent to about 100,000 calories to fix one gram of carbon. (This energy can be freed by burning the products of photosynthesis; better still, by burning alcohol derived from fermentation of these products.) Various estimates have been made of the amount of carbon fixed by plants. Schroeder in 1919 estimated the world's fixation per year as less than 20,000 million tons from plants grown on land. Seaweeds and floating unicellular plankton are computed to fix about 150,000 million tons per year. If the subject is approached by a consideration of the amount of available solar energy, it is found that the efficiency of utilisation of this energy must be quite low—of the order of 1% of the solar energy following on plant leaves.

Professor Gregory gave figures from his own experimental work over a period of nearly thirty years and from that of other workers, designed to find the efficiency of utilisation of solar energy. "The question arises whether plants vary in this respect as between species and varieties; and also whether efficiency can be increased by manurial and other culture treatments. The hope is often expressed of breeding plants with higher efficiency, and we shall have to consider the limitations of realising such hopes." He showed that with various plants in different places with different lengths of daylight, the efficiency varied only very slightly. It would appear, therefore, that no great differences in net assimilation (of carbon dioxide) can be expected among different plants. The mean value is of the order of 8 milligrams of carbon dioxide per square decimetre of leaf per hour of sunlight. Experiments on the percentage of total radiation utilised by barley have been performed for various stages of growth and condition of manuring, and in no case did it exceed 1·5%. "It appears, therefore," he said, "that neither by varying the plant or the fertility of the soil can the intrinsic efficiency of energy accumulation be greatly changed." But naturally "the total quantity of dry matter, and thus of stored energy, can be increased, but this is due to the more rapid development of the plants, their greater branching, larger leaves, and greater total leaf surface."

Bearing these considerations in mind, evidently the aim should be to maintain as close a cover of the ground by vegetation as possible. If it is to be utilised for power production the accumulated chemical energy must hold in chemical substances that are readily convertible by fermentation processes to alcohol. The most convenient substance would thus be either sugar or starch, preferably in the form of stored products in such storage organs as potato tubers or the sugar-beet root. The whole question of the relative amounts of utilisable products of carbon assimilation arises at this point, and here breeding and selection of suitable varieties would no doubt be of the greatest value. The most favourable conditions on which to base agriculture giving products for power generation would be the desert regions, where sunshine reaches a maximum; suitable irrigation would be necessary. Tropical regions with high rainfall and covered by rain forest are not so suitable; they would need great labour and expense for clearing, and there may be difficulties with disease and weed infestation. As for projects to use micro-organisms such as the green unicellular *alga Chlorella*, because of their high rate of multiplication and the ability to utilise the carbon supplied in carbonates. The advantages of the use of micro-organisms could apparently only be secured by growing them in vast shallow artificially heated tanks, provided with circulating devices and filter beds. On the whole the use of higher plants with storage organs would appear more economical.

Animal Hormones Present in Plants

OESTROGENS—female sex hormones of animals—also occur in plants. This was demonstrated a quarter of a century ago, when Loewe detected the presence of an oestrogen in plant tissue for the first time. (This was in fact the first animal hormone of any kind ever found in a plant.) In a lecture to the Agriculture Section, D. H. Curnow of the Courtauld Institute of Biochemistry said that oestrogens had been found in a variety of different plants and different organs—for instance potato tubers, parsley roots, cherries, plums, yeast, both kinds of willow catkins, oats and rhubarb leaves. "This diverse list of substances, gives us a view that oestrogenic activity may occur in almost any part of the plant and in almost any plant," he said.

The first oestrogen isolated from a plant was oestrone—from the oil of palm kernels. The second—oestriol—came from the female flowers of the pussy willow. These hormones have an effect on plants; thus oestrone added to the water or soil in which the plant is growing accelerates flowering in hyacinths, lilies, onions and maize. The early flowering may be due to a general effect of growth stimulation. A paste containing oestrone was applied to the stem of a plant called *Melandrium* and was found to stimulate the formation of 'female' flower organs; the male sex hormone, testostanone, had the reverse effect.

In Australia there is a well known sheep disease now known to be caused by the oestrogen in the plant called subterranean clover which is fairly common in pastures. It can lead to infertility in ewes. Much research in Australia has been done on this, and as an extension of this work a group of research workers at the National Institute for Research in Dairying, near Reading, has studied the oestrogens present in plants of British pastures. Red clover is found to be about a quarter as active (so far as oestrogenic activity is concerned) as the Australian subterranean clover. The effects that these oestrogens have on milk yield and fertility of British cows is being investigated at Shinfield. It is possible that the 'clover' oestrogen is oestriol.

The Australian workers are looking for a way of keeping subterranean clover in check as a means of controlling the sheep disease. It is already established that differences in the amount of phosphate fertilisers applied to the pasture land are reflected in the levels of oestrogenic activity of the clover.

Botanical Classification

SUBJECT of the presidential address to the Botany Section, of Dr. W. B. Turrill,

Keeper of the Herbarium of Kew Gardens, was "Modern Trends in the Classification of Plants". He stressed how knowledge gained in other rapidly advancing sciences, such as ecology, genetics, and biochemistry, had a bearing on modern taxonomy.

He drew attention to the dearth of trained taxonomists. "It is true that the demand for taxonomic specialists for filling botanical posts is not so great as it is for applied botanists. Nevertheless, it is increasing and is likely slowly, but steadily, to increase. There are signs that taxonomy is becoming reinstated in botany as a subject taught in our universities. We taxonomists appreciate the action of the University Grants Committee in making possible the creation of teaching posts in taxonomy in several university departments. It is particularly appropriate to express this appreciation here, since the first lectureship in botanical taxonomy under this scheme was filled last year in the University of Birmingham. Perhaps we may even look forward to the creation, in the not too distant future, of chairs of botanical taxonomy," said Dr. Turrill.

Dr. Turrill expressed the view that the taxonomist needed certain innate qualities, which he listed. "He must have a methodical mind with a liking for bringing order out of chaos. He should have a keen aesthetic perception of the beauty of shape, colour, and the relationship of parts. It may sound strange to include qualities usually considered the peculiar attributes of the artist, as necessary to the make-up of the satisfactory taxonomist. Yet, if you consider taxonomic practices it must become clear that quickened appreciation of curves and other outlines and of balance of organs aids comparison at every stage. There is no doubt that many taxonomists are born collectors. This may be interpreted as their being endowed with an undue share of the acquisitive instinct. This needs to be kept under control but, as expressed in herbaria, is at least relatively harmless and may then be regarded as a sublimation of such developments of the acquisitive instinct as shown by many historical figures, from King Solomon to Hitler and Göring." One incidental point he made was that the great rise in cost of reproduction makes the publication of first-class coloured plates of plants almost, or quite, prohibitive, and botanists would welcome research leading to methods of adequate colour reproduction at a reasonable cost.

Food Yeast for Farm Stock

THE need for breeding potatoes richer in protein which would provide a more nutritious feeding stuff for farm stock was mentioned by Prof. H. D. Kay in his presidential address to the Agricultural Section. He also advocated the development of food yeast production for the benefit of stock farmers. "I have wondered for some years," said Prof. Kay, "whether the nutritive value of potatoes for stock feeding could not be much improved if our potato breeders found it possible to incorporate into the modern high-yielding but protein-poor tubers the appreciably higher protein content of some of the lower-yielding strains imported some years ago from South America. Further, we have not yet seriously set about the problem of growing at a reasonable cost fodder-yeast for pigs and poultry from cheap carbohydrate plus inorganic sources of nitrogen and phosphate, either at home or in some tropical colony. A large industry of this kind might be developed in Jamaica or elsewhere using some of the by-products from sugar manufacture or even using crude sugar, provided that a correspondingly large demand for dried yeast, with its high content of digestible protein and B vitamins, its stability when kept dry and its other valuable commercial properties, could be fostered. One-thirtieth of the money spent on the ground-nut scheme would probably put this industry on its feet with, at home, great benefit to animal and fat production, and abroad, to Jamaican economy. There is no doubt about the high nutritional value of yeast for pig, fowl or dairy cow, provided a suitable amount of ground limestone is added to the diet. It would appear also that valuable feeds derived from fish by-products and from gluts of fish might be more thoroughly exploited and there are similar, though quantitatively more limited, possibilities regarding whale by-products."

General Science for Non-Scientists

ONE of the most challenging papers of the whole of the B.A. meeting was that of Dr. Eric James, High Master of Manchester Grammar School, who spoke on "Science in the General Education of the Non-Scientist"—and who also included some cogent remarks on the teaching of 'general science' to science students. Non-specialist science teaching, he said, should have these main objectives: the provision of a body of simple factual knowledge of some importance—given this, "a person of adequate general education will not assume a look of complete incomprehension when we speak about X-rays, vitamins or the atomic theory; an appreciation of the scientific method; a realisation of the relationship between scientific discovery and social change on the one hand, and the development of ideas on the other."

On the acquisition of the factual knowledge, Dr. James said this must not bulk too large or the teaching will become a mere presentation of snippets of information. But he stressed the need for a certain factual minimum, because of modern tendencies to ignore the fact "that education must be about something and because some critics of our education speak as though such abstractions as the scientific method could be taught as it were *in vacuo*". Nevertheless, said Dr. James, it is true that the second objective—the conveying of the idea of scientific attitude or method—is more important than any body of factual information. Dr. James considered there are two specific temptations to guard against here: first, the immense prestige and success of scientific investigation tempts us to regard the methodology as applicable to every problem and ultimately to assume that only scientific truth is true. Secondly, there is the danger of expecting too much from the inculcation of scientific method. "The belief that an education in science will at once make everyone behave rationally in every sphere of life—political, economic and personal—is a very simpleminded and indeed unscientific one," declared Dr. James.

What are the final aims of a general education in science? Dr. James saw it as an attempt to make clear the effects of scientific advance upon the organisation of society and upon the climate of ideas of the world in which we live. The non-scientist needs to be shown the fundamental changes science has wrought on the very texture of thought, as well as upon the physical environment.

Dr. James said it is most tempting to see the history of science as the solution to most of our problems. He expressed his belief that here is a very great field for advance and experiment, but he also said the difficulties of teaching the history of science are often underestimated. "A record of discoveries, theories and inventions will never capture the imagination of the non-specialist," said Dr. James. "An approach with a good deal more history and perhaps a little less scientific detail is what is required, in which the interplay of scientific advance, social change and developing speculation form a unified pattern." He referred to the new impetus to the study of the history of science given by men like Professor Farrington, Dr. Sherwood Taylor, Dr. Charles Singer, and Professor Butterfield, and said there is nothing that offers more hope than this of creating the needed kind of general science teaching.

Dr. James touched on the conditions necessary for fulfilling the aims of the general science teaching. He said it was obvious that these cannot be realised at all adequately by an education in science which stops at sixteen. Any real appreciation of the significance of science can only be obtained by minds that are beginning to ask and discuss some of the broader questions of life.

He came out squarely in favour of a sixth-form course in general science (as is provided in a few schools). He thought that here long sessions of practical work would bore students who "will have initially a very lukewarm interest in science—their enthusiasms lie elsewhere". The relationships of the science our pupils learn to their other subjects must be established by every means; thus, if they are historians, the relevance of science for the understanding of the medieval mind or the seventeenth-century background or imperial expansion must be emphasised. "The plan of science in the world, past, present, and future, must be made clear," he said. "*I would urge, too, that this kind of general science must be taught to scientists. Their need for a view of the wider relationships of their subject is no less than that of the classic or modern linguist.*" A suitable syllabus for this purpose has been worked out by the Science Masters' Association, and is being taught in several schools.

Dr. James concluded by drawing attention to the need for teachers of high quality to give such courses. He said that a

decline in the standard of science teaching would make impossible the general science teaching that is needed. "Just as it is far easier to teach about the Daniel Cell than it is to indicate the social effects of electricity as a source of power, so it is no doubt easier to teach Latin verbs than to make Hellenism a living force within the classroom. Yet faced with the problems of our time no general education that seeks to do less can be called adequate."

The Impact of Radio Talks on Science

FOR the first time a large-scale, scientifically planned research project has been organised to throw light on the factors helping or hindering a listener's understanding of broadcasts designed to convey information or instruction. The project was jointly undertaken by the Talks Department and the Audience Research Department of the B.B.C. in co-operation with a team of outside specialists. The latter was headed by P. E. Vernon, Professor of Educational Psychology in the University of London. He and Mrs. Vernon prepared a paper on the subject for the Psychology Section, and this was followed by an account by Mr. J. Trenaman, Assistant Further Education Officer of the B.B.C., of the methods used to test listeners' understanding of three informative programmes about science.

The main inquiry covered fifty actual programmes ranging over three months and a half from the normal output of Forces Educational Broadcasts in the Light Programme, and the subjects covered were Current Affairs, Science, Citizenship, and the regular series called "Plain English". The broadcasts varied from straight talks to dramatisations. Listeners in Army groups and among civilians took part in assessing interest and intelligibility in the programmes covered, the method of assessment being a rating of a number of chosen factors. Of the total 4600 test papers completed, 3200 were from Army groups.

The first result of the inquiry, as reported by Professor Vernon, was that with the 30% of the population with some secondary schooling or higher the programmes were reasonably successful, approximately half the main points being grasped. With the remaining 70% of listeners, understanding often proved to be severely limited. That is to say, just over half of a representative cross-section of the population seemed in general to get little or nothing by way of knowledge from the average broadcast even though its level was comparatively elementary (such as the Forces Educational Broadcasts in the Light Programme).

The most important conclusion drawn from the experiment was that the factor having most bearing on intelligibility was the interest-value (a complex thing needing further research as Professor Vernon showed later) of the actual *content* of the programme, rather than the general style or method of presentation.

"Many of the current affairs, science and other talks which get across best," said Professor Vernon, "were among the more complex in style and language, whereas English-teaching and other talks that bore the hallmarks of good construction and style often proved so uninteresting in their content that listeners' responses were low." Lucidity, strict limitation of the number of main points and clear summaries at the end of a broadcast were all of considerable help to listeners. Concreteness as distinct from abstractness, especially at lower educational levels, and the use of active verbs equally helped to promote intelligibility. Too much illustration, however, could be dangerous, the listeners remembering the image but not the point it illustrated. Listeners' comprehension seemed little affected by the vocal qualities of the broadcaster. Long words were not as much of a handicap as long sentences. One very important conclusion for broadcasters and programme organisers was that the correlation between the educational levels of individual listeners and their intelligibility scores in the standard test used was very high. (In other words, the better the listener is educated, the more easily he understands, which may seem obvious but has not up to now been established quantitatively.)

There was no agreement on the factors involved in such a vague quality as "personality". And the "interestingness" that played a marked part in promoting comprehension was also "very difficult to predict". These facts showed the need for still further research limited to one or two factors at a time. Professor Vernon urged this need for further research within the field of intelligibility.

Mr. Trenaman's paper gave a very detailed account of the more restricted experiment, with explanations of the statistical methods involved in assessments. It was found that marking on a points scale—5 marks for a principal point fixed in the listener's mind by the broadcast, 2 or 3 for less important points, and so on—was in excellent agreement with estimates made independently by a number of science teachers. Immediate recall and remote recall (a week after the broadcast) of particular points made in the programme and so on were taken as the tests to be applied.

For the first talk, on electrons, samples of listeners (264 of them) were drawn from six distinct educational levels, all the listeners being in the age group of 16 to 19 years. "It was found that the scientist's talk on electrons was sufficiently understood by graduates and undergraduates; by a majority of the grammar school sixth-form listeners; only by a minority of the technical students and not at all lower down the scale. It follows that only about 10% of the population could have grasped very much of the scientific facts and principles of this broadcast, although it was intended for the general public, and the speaker, a scientist, had been at great pains to make it simple. An analysis by B.B.C. Audience Research Department of the social grade of listeners to the talk on electrons shows that it reached 8·5% of the lower middle class and only 1·5% of the working class."

Much Simpler Talks Needed

Mr. Trenaman's final sentences summed up the results. "It seems clear that the problem of interesting the general public in science demands the provision of spoken-word broadcasts at several different levels of difficulty, and here difficulty must evidently be measured in terms of assumptions made as to background education in science. The short talk on science for the general public, measured in terms of the majority of the population, would have to be very much simpler than the usual run of such talks to be, in fact, intelligible."

The Clear Exposition of Science

A COMPLETE session of the Engineering Section was devoted to discussing the presentation of technical information, and it was attended by many engineers. Professor R. O. Kapp, whose book on the presentation of technical information is well known, developed the theme that talk and paper are among the most important tools with which engineers and scientists have to work, and yet badly constructed reports and papers are tolerated. This is a modern development, for among the writing of eighteenth century scientists one may find much that is a pleasure to read. The reason for the decline in standards of exposition may not be clear. "But whatever be the reason it remains true, unfortunately, that scientists of these times show an inadequate awareness of those who are to read or hear what they have to impart. Even those who command a polished style are not always good expositors; it would be more accurate to call them accomplished soliloquisers."

He expressed the view that there are three aspects of the expositor's art: linguistics, logic and psychology. The first of these is the least important.

Professor Kapp made a strong plea for the study of exposition. "Let us attempt, deliberately and systematically, to raise standards of exposition; let us take the technique of that art more seriously than we have done in the past; let us study that technique in all its aspects; let us attempt to perfect it, to teach it. Until that is done scientists must continue to be hampered by the bad work of poor expositors."

Mr. J. Bainbridge-Bell, of the Admiralty Research Station at Haslemere, whose powers of exposition are known to all who have worked with him, followed with a paper on the need for clearer electrical circuit diagrams.

He illustrated his talk with examples of different diagrams of the same circuit unit, in one instance the unorthodox arrangement being defended by the draughtsman because there was, he said, a rule in his firm that the spirals representing coils always had to be vertical! Mr. Bainbridge-Bell, contesting the view sometimes expressed that it is quite a good thing to make a diagram rather difficult to interpret, asked if a man would prefer to put a request for a rise in salary in the form of an acrostic. An exhibition of diagrams redrawn according to the new principles was given in a room adjoining the lecture hall.

FIG. 1.—This termite tube was built up from the ground to a wooden joist 15 inches above: on the floor are the remnants of tubes which collapsed before reaching the joist.

Life among the Termites

ALAN GOODMAN, M.Sc.

ALICE began her wonderland adventure when she fell into a rabbit hole. There she met strange creatures whose foibles we lament in our friends; had she fallen into a termite colony, her fellows there would have possessed all those qualities we own as virtues in ourselves. Travellers like Henry Smeathman in 1781 praised termites as being sagacious and industrious; indeed these insects were said to "surpass all other animals . . . in the arts of building . . . as much as the Europeans excel the least cultivated savages."

Termites, small wingless insects less than ¼ in. long, live in permanent colonies; and like bees or ants, the members of a termite colony are physically adapted to the different tasks they perform: indeed termites excel all other social insects in the variety of types or castes within their colonies. In some nests there may be three kinds of kings and queens, at least two kinds of workers, several sorts of soldiers and juvenile forms of the different kinds at various stages of development. There are no workers in colonies of *Kalotermes* where the work of the nest is done by the juveniles, whilst in the special case of *Anoplotermes* there are no soldiers and the nest is defended by workers.

Like that of their near relatives the cockroaches, the development of the young termite is continuous and the smallest forms are not greatly different in appearance from adult types. It is during development that the differences between the various castes of termites become apparent.

In the evolutionary history of the termites, winged or breeding types were the first to appear; later it is probable that in some fossil species there was a gradual change and many of the individuals although capable of breeding rarely did so, and were particularly concerned with the defence of the colony. In this way, the earliest castes—soldiers and the royal castes—arose. Even today in the primitive termite genera *Zootermopsis*, *Archotermopsis* and *Mastotermes* the soldiers are sometimes fertile, bear wing rudiments and have some of the external signs of sexuality. The worker caste is not typical of primitive termite colonies and probably was not present in the colonies of species known only as fossils. Like the juveniles which they resemble in size and appearance the workers do the chores of the nest and only rarely do they take part in fighting.

Some 250 million years ago the ancestral termites lived on the humus rich floor of primeval forests. They lived in groups, like modern earwigs, under stones or beneath the bark of fallen trees; from this state it is but a short step to the mode of life of modern termites which live wholly concealed in the soil or within a piece of timber, from which they only emerge to found new colonies. Within the soil the termites are secure from the attacks of their

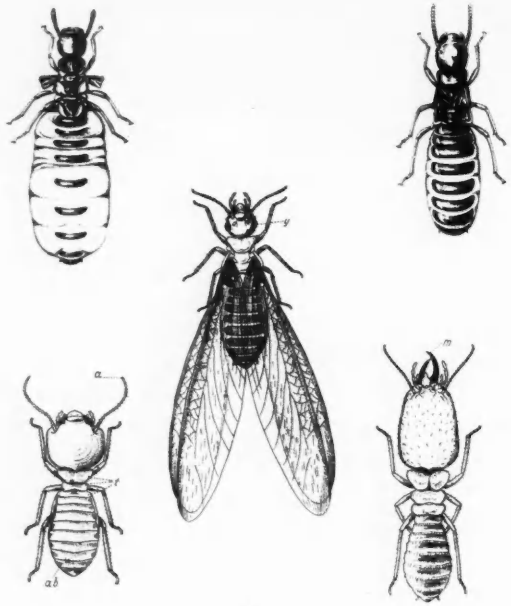


FIG. 2.—Queen (*top left*) and king (*top right*) of *Reticulitermes flavipes*; (*centre*) winged form, (*bottom left*) worker and (*bottom right*) soldier of *Bellicositermes natalensis*.

enemies; they live in a stable moist environment and are surrounded by a vast supply of food—the humus—for which they have few competitors. Under these conditions reproduction is rapid. The colonies consist of equal numbers of males and females though few of these are sexually active; however this disability of the many ensures that food gathering and defence will not be interrupted by egg laying.

The darkness inside the nest has resulted in the loss of functional eyes, but the insects have highly developed senses of smell and touch. (Exceptional are some thirty species with functional eyes.) Foreign insects, even of the same species, are immediately detected and destroyed, but if the intruder survives long enough to acquire the odour of the nest it is allowed to remain unmolested. There are exceptions to this general rule, as occurs when different kinds of insects—called termitophiles—live as guests of the termite and share their food; in a few cases two species of termites share a nest as equal partners.

An important aspect of communal life is the termites' habit of sharing food. Not only do the workers feed their royalty and soldiers with partially chewed material, but a worker with food in its jaws will divide this with its fellows. It will also lick the fluids exuding from the anus of another, and this anal feeding is frequently used to nourish the tiniest juveniles. Termites also will eat each other's faecal matter. The significance of this group of habits will be later seen in connexion with the protozoa which inhabit the guts of termites.

The insects frequently lick or 'groom' each other. In this way they obtain some body secretion of unknown composition and function; indeed so vigorously are the reproductive pair groomed that their attendants may nip off small pieces from the royal limbs. Grooming may be of importance in regulating the numerical proportions of the various castes in the colony. It is believed that soldiers and the reproductive pair secrete substances—ectohormones—in the fluids licked from their bodies, and these substances inhibit the development of juveniles into the same caste or sex as the insect producing that inhibiting ectohormone. Thus in a small colony the ectohormones from the royal pair prevent juveniles from developing into new kings and queens, but in a large colony where juveniles are separated by distance from the royal couple new egg-laying types may arise. It is possible that caste regulation is a more complex matter than is represented by this ectohormonal theory, and that genetical and feeding differences may play their part.

Sometimes the nest is just a piece of wood in which the insects burrow, as in the case of the Powder Post Termite whose soldiers have huge heads which are used to block internal passages should the colony be invaded. Wood-eating species never damage the surface of the timber in which their burrows run. Like many other species the jaws of these wood borers are richly supplied with sense organs and it may well be that the insects working near the surface of wood are thereby warned of its nearness and divert their burrows accordingly.

The very destructive subterranean termites build a central nest from which by long tunnels they spread to smaller sub-colonies or go in search of food. It is from these tunnels that termites gain access to houses through whose constructional timbers they rapidly spread.

The walls of a termite nest may be 20 to 30 centimetres thick and are made of particles of earth chewed and stuck with the termites' saliva into a brick-hard mass. Sometimes these mounds are furnished with water drainage shafts: Dr. Bathellier found a mound nest of *Macrotermes gilvus* in which had been constructed several large empty chambers below ground level. From each of these chambers ran a number of parallel channels, downwards into the soil. In Bathellier's view these cavities and galleries served for the "drainage of the water and for its absorption by the soil". The caps on top of some of the smaller nests serve to deflect rain entering the nest. *Apicotermes*, a species from the Lower Congo, builds a small mound whose walls are penetrated by many tiny air vents.

Whilst the nest remains undamaged it affords protection to its blind, soft-bodied inhabitants. The soldiers, whose jaws and heads are adapted for fighting, are in effect only adapted for defence of the nest. Normally they fight with their abdomens concealed within the nest, and when a breach is made in the wall the soldiers arrange themselves in an arc, with their heads pointing outwards whilst their soft abdomens are protected by the passage-ways of the nest. Ants, the termites' chief enemy, rarely succeed in a frontal attack upon a group of soldiers, but try to approach them from behind to reach the vulnerable abdomen.

Inside the nest the air is moist, and to maintain a suitable humidity the workers bring water into the nest. Moisture is vital to these creatures and if they are forced to live in dry air, fluids evaporate through the delicate skin of their bodies. The covered ways which many species build over the walls of houses or along the trunks of trees are simply extensions of the nest and of the protection it affords the

termites. Except in the case of foraging termites whose bodies have hardened skins, workers and soldiers never normally leave the nest.

Not only is there mutual dependence between the individuals of a colony, but in many species the insect is dependent for its food upon the small creatures which live in its gut. Although the termites eat large quantities of cellulose in the wood and humus they consume, they are unable to digest what they eat, and it is the role of the protozoa which the insect harbours in its gut to digest what the termite has eaten. Following each of the 5 to 7 moults during juvenile development the whole of the gut protozoa are lost, so that reinfection must take place before the newly moulted termite can continue to digest what it eats. This reinfection occurs if the juvenile licks the anal exudates of another insect, if it takes food from the jaws of another, or if it eats the droppings of a termite. In addition to the unicellular animals, there are also bacteria present in the insects' gut and it is probable that these micro-organisms may supply the insect with vitamin substances. The role of these bacteria is by no means clear.

Mound-building and other subterranean species harbour special masses of fungi within their nests; the fungi, some of them mushrooms, grow upon spongy masses of chewed wood which the termites provide. The workers break off small pieces of the fungal growth which they feed to the royal pair, whilst the juveniles graze on these fungal gardens after the manner of miniature sheep! *Gnathamitermes*, a desert species of America, builds earth tubes over every part of small herbs; within the tubes, plant tissues soon decay to provide food for these termites. Foraging termites regularly leave the nest in long files protected on either side by soldiers, in search of grass stalks, lichens and seeds, the chief foods of these species.

During the formation of a new colony several new aspects of termite behaviour are revealed, a pattern of behaviour which is similar in all species. Each year during the months preceding the rainy season, large numbers of juveniles develop long filmy wings.

These winged forms (alates) are the distributive phase, and in form resemble the ancestral termites. Immediately after the first rains have softened the soil, workers open passages out of the nest and soldiers stand guard at each opening. Presently thousands of the alates move eagerly out towards the light. They spend a few moments on the ground outside the nest and then take flight. Their flight is generally weak and uncertain; some flutter only a few feet, others a hundred yards, whilst the wings of others fall off while the insect is airborne. Many flying termites drop into water where they drown and many fall to the ground where they are eagerly devoured by the large number of toads, frogs, birds and lizards which assemble near the nests at the time of the colonising flight. Usually mating does not take place until after the alates have landed and shed their wings. Few of the thousands of alates of a swarm escape the attacks of their foes and succeed in pairing, an act initiated by the female. She raises her abdomen and probably emits some attractant odour; meanwhile the males hurry about until one by one they meet females. The female lowers her abdomen, and moves off with the male following; sometimes unpaired males follow behind the first, until there may be a string of three or four behind a single female. If the female veers round in a circle to meet the hindmost male the whole procession rotates for a while until the female changes direction again. During this activity the female, although previously attracted to light, becomes repelled by it and her processionary movements show her to be seeking shelter. Soon she finds a crack in the rain-softened earth and then both she and her hitherto passive partner begin to excavate their first nest. Unpaired males do not interfere with this act.

The pair dig themselves a cell an inch long and an eighth of an inch wide and seal off the entrance. During this period the insects do not eat but live on the fat of their wing muscles. Even now the perils of the couple are not at end. Some may dig too large a cell and perish of fatigue, others may pass into a period of rest and may die, whilst others may enter parts of an established colony and be killed by the inhabitants. During the next month about ten eggs are laid, and these hatch usually six to eight weeks later; meanwhile the young couple enlarge the nest, and from time to time they scrape the eggs with their jaws to remove the moulds which grow on the surface.

After hatching, the young assist their parents in the work of the new colony, but remain small, and for as long as two years after founding, a colony may contain only the royal pair and dwarf workers. As the food supply becomes more plentiful, juveniles develop into the other castes.

In nature the termites' role is that of scavenger, and its burrows serve to drain and aerate the soil in a way similar to that of the earthworm's burrows. Smeathman points out that no other animal is so expert at destroying every trace of dead vegetation, thus clearing the soil for the growth of new plants.

It is mainly where man has upset the balance of nature that the termite becomes a serious pest. During World War II, mound-building species damaged the runways of tropical airfields and much damage was caused by other species to stores of clothing and equipment. Wooden fence posts, pit props and wood framed buildings, unless carefully treated with poisons, are attacked. In 1934, termites in America did an estimated forty million dollars' worth of damage to property. To this figure must be added the cost of termite-proofing new and existing buildings. Although primarily soil inhabitants, some termites lead lives very like those of wood-boring beetles and will attack seasoned wood and furniture; others by means of the acid secretion of their nasute, or snouted, soldiers have attacked lead-covered cables or have passed through brick walls into the basements of houses. Termites will attack growing crops of all kinds, and have done much damage to teak and tea plantations in the East as well as coffee, cacao, and sugar-cane in various parts of the world.

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As biological science has grown more specialised the gap between professional biologists and amateur naturalists has tended to get wider. These two articles discuss the need to bridge the gap and offer suggestions as to ways in which co-operation between the two kinds of workers can be extended. Major Maxwell Knight is a well-known amateur naturalist and president of the Camberley Natural History Society; Mr. Bruce Campbell is secretary of the British Trust for Ornithology.

Unsolved Problems of Natural History

A PLEA FOR COLLABORATION BETWEEN SCIENTISTS AND AMATEURS

MAXWELL KNIGHT, O.B.E., F.L.S.

A FIELD naturalist is always encountering problems to which the solutions may be absent entirely, or are the subject of much discussion and argument, or which are skilfully avoided by all except the adventurous and the insatiably curious.

I suppose that every naturalist has his own pet problem to intrigue him, and also his own pet myth to infuriate him. One such myth is that connected with the swallowing of their young by adders. I expect that most people are vaguely familiar with the story: an adder is seen curled up on a bank surrounded by her family—incidentally a thing which very rarely occurs. Along comes a human being; at once the parent adder utters a loud hiss, and the young—anything up to a dozen or so—proceed to disappear down their mother's throat! Then when danger is past they duly emerge again.

Only a year or so ago I took part in a broadcast about British snakes, together with Mr. J. W. Lester, Curator of Reptiles to the London Zoo. In the course of the talk we were asked to say something about this question, and to the best of our joint abilities in the time available we did so. What was the result? Dozens of letters reached both of us reproaching us for our unbelief, and expressing indignation that we should stigmatise those who believed in this story as either deluded or untruthful.

Now the curious point about all these letters was that not one of them said . . . "I saw this happen". They were all second- or third hand accounts and therefore valueless as proof of anything except the writers' credulity. Yet the evidence against the myth is overwhelming.

This brings us to the next point of objection, the actual swallowing. Now snakes are not constructed to gulp; their teeth cannot chew; and they engulf their prey rather than swallow it. Now, seeing that the young adder may be from five to seven inches in length, it will be obvious that swallowing even one of them would take some minutes. Yet we are asked to believe that the whole family vanishes in a flash! Is there any need for further proof of the absurdity of this age-old fable? Perhaps it is just as well to dispose of a sort of trump card frequently produced with an air of triumph by the protagonists of a display that would put a sword-swallower to shame.

It is often alleged that when this occurence has been observed, the adder has immediately been killed, and, lo and behold, the family which sought refuge by returning once again into their mother's womb in defiance of the Scriptures, have been exposed to sight by the furious blows of the eager but too violent assailant. I am of the opinion that the killing of a gravid female probably forms the basis for the original myth.

But, of course, it proves nothing. What has happened is clear to anyone possessing some knowledge of adders. One or two young having been born—possibly a quarter of an hour before the adder is first seen—and the day being hot, and the young snakes dried off sufficiently for quick movement, they may still be *somewhere* near the parent adder. The earnest spectator approaches, probably with feelings of excitement mixed with fear. The young adders slither away into the nearest undergrowth and vanish from sight. The adder is killed and the remainder of the litter, as yet unborn, are forced into view.

Let us now turn to mammals, and the question of whether it is true, or even possible, that hedgehogs sometimes roll on fallen apples, impaling them on their prickles for future consumption.

Mr. Frank Lane in his interesting and instructive book, *Animal Wonderland*, devotes some considerable space to this problem; and it would be a waste of time to go over the same ground here. It has always struck me, however, as very curious that none of those who have addressed themselves to this matter seems to have tried to experiment in order to see the degree of likelihood attaching to such a phenomenon. Now I have done so; and though it is dangerous to dogmatise, the results of my experiments seem to show that the impaling of apples on the spines of a hedgehog is a very difficult task indeed.

For one thing it depends a great deal on the type of apple. Crab apples are favourites in the recorded accounts, but a crab apple is a small, tough-skinned fruit, and not, one would think, very easily pierced. Larger apples have been quoted, but the variety of apple is seldom mentioned. I will admit that a rotten or semi-rotten apple would offer little or no resistance, but would it stay *in situ* once it was impaled on what are, after all, very mobile and not over-long spines?

When I was a boy I remember reading of this exciting legend in a book, and being of an inquiring mind, and having a pet hedgehog, I tried various means of proving the case. First of all I placed some apples in my pet's enclosure and it took absolutely no notice of them. Then, my enthusiasm outstripping my humanity, I dropped a medium sized apple on to my hedgehog's back. Did it stick? No. This may prove nothing much, for my pet was frightened and curled up at the first touch, but at least in this position its spines were definitely erect. Next I tried rolling the hedgehog on to the apples. This was a failure all round—the only pricks were made in my fingers, so I gave it up.

More recently I have experimented again with apples and a piece of hedgehog skin, and even then I failed to achieve the desired result; and so, for the moment at all events, I remain unconvinced. Photographs seem to me to prove little unless they are taken under test conditions by naturalists

of proven knowledge and probity. I have said nothing about why the old hedge-pig should want to do all this, for it is doubtful if he is more than occasionally vegetarian in his diet. Also I have not touched upon the further problem as to how, granted that the apples do become firmly impaled, the creature gets them off again—or where he does it.

Enough of myths. What about the many problems awaiting solution which are less tainted with the aroma of Old Wives' Tales: what is the truth about the snake charmer's pipe? How does a dog or a horse know that a person is afraid, even if that person makes no obvious movement of a nervous nature? Does the woodpecker produce the drumming note vocally, or by actual tapping with its beak? These are mysteries but not fables.

It would be a very good thing if natural history societies included in their programmes more discussions on controversial matters, and fewer lectures on topics which have been fully explored. Many sound suggestions might arise in the course of debates, and these could be passed on to persons dealing with the strictly scientific approach. It should never be forgotten that the amateur naturalist has been responsible for a host of original discoveries; nor that the field observer is the person most likely to supply the clue, if not the answer, to some of these mysteries. The ideal to aim for is the closest co-operation between workers in the field and those in the laboratory and museum: an association born of mutual respect and a sense of proportion, and without that streak of rivalry and even of patronage which sometimes creeps in.

Well, what about the woodpecker and its drumming? There are two schools of thought—those who think that the noise is the result of the impact of the beak on wood, and those who maintain that it is vocal. The protagonists of the mechanical school, so to speak, are vastly in the majority; but the others are frequently as vocal as they claim the woodpecker to be, and they persist in refusing to believe in the possibility of such a rapid note being made by movements of the head, which, incidentally, are said to be as many as a dozen per second! In my opinion here lies the weightiest argument in favour of the supporters of vocalism. Anybody can try vibrating their tongue against the palate or teeth, and can realise by doing so what a speed can be worked up—a speed far greater than any other *sustained* voluntary movement of which we are capable. This being so, may it not also be true of the woodpecker? It is certainly true that the exact mechanism which might enable a woodpecker to drum at such a speed with its beak is not properly understood, but this does not put the 'drummers' out of court. They affirm that if the noise were vocal, it would sound the same no matter what substance happened to be facing the woodpecker when this display sound—for that is what it is—goes on; and they point out that there is abundant evidence that the note definitely changes when the bird drums against a metal band on a post, for instance.

I am no expert on sound, but I am tempted to wonder if this argument really does invalidate the vocal theory. If a musical instrument such as a trumpet is played into a metal container—a saucepan for example—and then this experiment is repeated with a similar container made of wood, the sound produced will be quite different in each case. Therefore, is it not at least possible that if a woodpecker does make this sound vocally, there would still be noted the varieties in tone which have been heard and reported times beyond number?

I would like to see some attention directed to two lines of inquiry. First, an attempt at making a high speed film of a drumming woodpecker; and second, a 'recording' of the drumming, by means of a microphone, under as many different conditions as possible.

The perception of fear by an animal is perhaps a more tricky affair to discuss, but it is equally intriguing. How do some animals know that a certain person, who may be doing nothing at all in the way of shrinking or moving away quickly, is afraid? I have been told more than once by real country folk that it is possible for an animal to 'smell' fear; and that this is the explanation for aggressive behaviour on the part of the animal in question. It knows the other person is afraid of it, and therefore feels itself superior and does something to assert its superiority.

It is well known that two people can go to handle an animal such as a ferret, and both may make exactly the same movements. One will be bitten and the other not. It is known that the adrenalin which is secreted by the adrenal glands is poured out under the stimulus of great fear or anger, and it is also well known that a frightened person breaks out into a cold sweat. Therefore, is it not quite possible that chemical change takes place which gives rise to an odour easily perceptible to mammals which have such an ultra-keen sense of smell?

Now, to return to snakes. Thousands of words and hundreds of accounts have been written about the work of snake charmers. A vitally important part of the so-called charming seems to be played by the traditional pipe which is said to call forth the snake, to quieten it, and even to make it dance. This would be wonderful, even if the snake was known to rely upon its hearing; but as snakes are deaf and have no organs of hearing as we understand them, the matter becomes more complicated.

But the stories of snake charmers' efforts cannot be dismissed as mere rubbish; there are too many well authenticated accounts. What then is the answer? So far as the dancing goes, I believe that the truth lies in the slow rhythmic movement made by the charmer as he plays his pipe. He sways to and fro in front of the snake, and the snake tends to follow the movements of the man and his instrument. I have experimented in this way myself, and I am satisfied that snakes will frequently follow the movement of a hand or a stick with absolutely no musical inducement whatever. I have also played whistles, and even a clarinet to snakes, but without the slightest success in the way of body movement on the part of the serpent *so long as I remained absolutely still.* I have, however, frequently noticed that when a particularly high piercing note is produced the snake's tongue will protrude and flicker; and this suggests that the tongue, which in snakes is primarily an olfactory organ, is also sensitive to vibrations. That snakes are very susceptible to earth tremors and to vibrations against their cages is well-known; and if they are equally sensitive to air-borne vibrations, then this may well explain even their being called forth from holes; for they are very curious creatures and, if not frightened, they like very much to ascertain the cause of anything that has aroused their interest. Here again is scope for experiment—and it need not be very difficult to carry out.

There is a further piece of research, well within the scope of the amateur, that would, if brought to a successful conclusion, make a genuine contribution to science. This concerns the problem of how frogs, newts and toads—particularly toads—find their way to the water when, after hibernation, they prepare for breeding. Amphibians breed in water, and although frogs frequently hibernate at the bottom of ponds, this is not invariable; while newts and toads hibernate on land, frequently quite a long distance from the breeding place. Yet year after year they repair to their regular resorts. How they find their way is not known, and no systematic work seems to have been done on the subject.

Go to a pond where toads are breeding. Take one or two out of the water, and go some distance from the pond. Now place the toads on the ground with their heads pointing away from the water. At once they will turn round and start to return to the place from which they have been taken. There is no hesitation, no casting about. They instantly know which direction to take, and if left alone will soon be back in the water again.

There have, of course, been suggestions from time to time as to the reason for this ability to find their way to selected ponds, but none of the suggestions seems to me to be convincing. Smell has been a popular theory, but not much work has been done on the olfactory powers of amphibians in any case, so one is left without a basis from which to work. Another idea is that, as the males of all amphibians emerge first from hibernation, the croaking of the first arrivals guides the others to the water. This is all very fine if not subjected to close examination. It may be true that toads use their croaks as a sort of mating call, but how does the very first toad find his way—who or what guides the pathfinder? Again, even if this is true of toads, it cannot apply to newts which have no voice with which to call, though they too travel some distance from their hibernacula to the breeding grounds.

No; the solution is not so simple as this, and in order to arrive at any conclusion some really co-operative work must be carried out between physiologists, zoologists and teams of field naturalists. During the right season—March and April—a systematic watch should be kept in various likely localities for the first signs of toad activity. As soon as the first toads are seen on the move, careful note should be made of the direction from which they appear to be coming, and their routes should then be traced back as far as possible. This would at least give us some idea of the distances travelled and would also solve the problem as to whether the ponds are approached from all points of the compass, or whether there seems to be some special direction from which the toads come. Another method would be to locate two or three hibernating toads and watch for their emergence, after which it should be easy to track them to the water, time the journeys and observe the general behaviour; watching in particular to see if others are met up with, or if the toads go their own individual ways.

These are not easy tasks. It is probable that such migrations take place at night; the exact time of emergence from hibernation cannot be forecast—the prevailing weather has a great deal of bearing on this. But as toads are most conservative in their breeding haunts, and as hundreds congregate each season, it should not be impossible for something to be done towards lifting at least one of the veils of mystery which surround some aspects of animal behaviour.

Co-operation in Zoological Studies

I DO not altogether accept Maxwell Knight's implicit distinction between the professional zoologist as a laboratory and museum worker and the amateur as the man in the field. I work surrounded by a department of field studies, staffed by professional zoologists, who seem to spend most of their time in actual observations, disappearing for months on end, sleeping out so as to be on the job for the vital hours before and after dawn; often not sleeping at all when their subjects are mammals or owls. Naturally, a proportion of their time is spent in workshop, laboratory and library, but one striking change in recent years has been that the professional is now able to devote much longer periods to field study than is the amateur.

There is, however, no real difference between the two categories; they shade into each other. At one end of the line, so to speak, are trained zoologists whose main work is teaching and who cannot give more than part of their leisure to personal research; at the other end are retired men and women from other professions, people who have accumulated a great deal of zoological knowledge in pursuit of their hobby and are now free to spend all their time on it. And there are all sorts of gradations in between.

The British Trust for Ornithology has been studying this question of co-operative field work for seventeen years, and this relatively long experience, coupled with the enormous interest taken in birds by people of very different abilities and opportunities, entitles the methods of the Trust to be discussed at some length, although no one connected with it would claim that a perfect technique has yet been worked out. The views that I shall express are not necessarily those of the Trust; on the other hand they are not entirely my own, because, during the past two years, I have talked this problem over many times with friends and colleagues.

The British Trust for Ornithology cannot claim any proprietary rights in co-operative field work with birds. Very similar methods were used by the British Association and by the British Ornithologists' Club in their studies of bird migration many years ago, and it is not far-fetched to see the germ of the idea inherent in Gilbert White's circle of correspondents. But the term Co-operative Inquiry did come to have a rather specialised significance and use in the investigations sponsored by the magazine *British Birds* shortly before the formation of the Trust, which, indeed inherited the most famous of them, the annual sample census of heronries, now twenty-three years old. In a Co-operative Inquiry, observers all over the country are linked together by a central organiser, to whom they send in their information, and who is responsible for drawing up the final report and for calling in

expert advice as he requires it. It has been a feature of inquiries run by the Trust that the organiser has seldom been a professional zoologist, but that the inquiry has been agreed upon and the report submitted to a Research or Advisory Scientific Committee, on which sit both professional—*sensu stricto*—zoologists and men who have devoted the free hours of a lifetime to studying birds. Usually one or two members are particularly interested in each inquiry and keep in close touch with the organiser.

The social results of this method are excellent: it gives bird-watchers, who have tended, until the recent vigorous revival of local societies and clubs, to be—like some of their subjects—"rather solitary in their habits", a sense of unity and companionship and, as originated by the journal *British Birds*, it paved the way for the formation of the British Trust for Ornithology with its emphasis on the communal study of field problems. Scientifically, however, there must be criticism of any technique which appears to place equal reliance on observations from experienced naturalists and from beginners. The chain is as strong as its weakest link and the more observers that join in, the greater is the risk that accuracy will be sacrificed to what is really education. It is sometimes extremely difficult to separate the educational from the purely research aspect of a proposed field study, but the Trust has always tried to avoid approving any investigations, the objects of which are really to educate or, worse still, simply to occupy its members.

Careful choice of subject is the best way to meet criticism of the co-operative inquiry. There are some problems, especially concerning distribution and migration, which can be made practically foolproof; inquiries involving estimates of population, however, are much more dangerous, and are not now encouraged as 'open' investigations.

Various modifications of the original concept have been adopted to preserve standards of accuracy. An organiser may conduct his inquiry through a limited group of correspondents of proved experience, or he may delegate to local organisers, who can sieve information in their own regions before sending it on to him. A good example of this is the ten-year census of the Great-crested Grebe, over a sample area mainly in the English Midlands, which began in 1946 as a follow-up to the original national survey of 1931.

But there are still investigations in which the net can be cast as widely as possible, far beyond the numbers of those normally interested in natural history. The inquiry into the opening of milk-bottles by birds*, and the current investigation of the paper-tearing habit in birds used various appeals for information and aroused great popular interest. The 2500 communications on paper-tearing received by the organiser, Lt.-Col. Logan Home, must be a record for any natural history inquiry, and covered a diversity of incidents from a 'mass-attack' on the chapel tower of a public school to the puncturing of a bicycle tyre by a blue tit.

The co-operative technique has not only been used for bird problems. In Monica Shorten's study of the status of the grey and red squirrels in Britain†, a research worker at the Bureau of Animal Population, Oxford, corresponded with voluntary observers all over the country, while Sir William L. Taylor's surveys of the distribution of wild cats, capercaillie and wild deer on Forestry Commission areas* have shown how the staff of a widespread organisation can contribute useful data as a by-product of their main work.

There remains a danger, however, that co-operative inquiries, though they are carefully chosen and admirably supervised, may breed a race of part-time naturalists whose only research lies in these inquiries. The demands of the annual census of heronries, or of grebes, or of the periodic wildfowl counts organised by the International Wildfowl Inquiry, are not excessive. Any keen observer should have time as well for his own study; indeed, it has been suggested that the member who has conducted his own field-work becomes much more valuable as a participant in co-operative inquiries.

We need to encourage the study of the very common, as being by far the most likely source of results that are worth having. Could we ask the members of a natural history society the question: "If you had six pairs of greenfinches nesting in your garden, and one pair of hawfinches, which would you choose to watch?" I wonder what they would answer. To the scientist there could be only one reply.

If our work is to have significance, both in the statistical and the ordinary meanings of the word, it is the number of observations which count, and though it is at first hard to say: "Sorry, I can't come with you to the sewage farm or the reservoir; I must watch my greenfinches," the fascination grows as the notes mount up and the glimmerings of an explanation of the observed phenomena first suggest themselves from the mass of data.

For the observations must come first. To test a theory born of armchair discussion may seem fine, but the method of the scientist is inductive. One observation poses a question, a second reiterates it, but only an accumulation of data warrants the erection of a theory. And then the observer must apply every possible test to his theory, probing every possible crack in the edifice, until he is absolutely sure that it hangs together, each brick a solid, observed fact.

With this accumulation of observations there must also be accuracy. Nothing more must be inferred than is actually seen, and there must be certainty about what is seen. I can give two examples to illustrate this. Walking up a road under the beech trees one October afternoon, I came on a hedgehog busily chewing something. It was surrounded by newly fallen beech-mast and the temptation to believe that this was the food taken was strong. But I separated the urchin somewhat unwillingly from its meal, which proved to be the stalk of a pear. Secondly, a friend of mine was assured by a relative that starlings had stripped a certain holly tree. On being questioned, she said (*a*) that the the tree was now bare, (*b*) that starlings often perched; but she had never actually seen them eat the berries: her mind had jumped the gap without knowing it. Again and again the answer is not what it appears to be, and the only way for the scientific observer, whether he is giving one hour or one hundred hours a week to his study, is that of ruthless criticism, first of the power of his own senses to record, then of the inferences which his mind rushes in to draw from those records.

* Fisher, J. and Hinde, R. A. (1949), *British Birds* **42**: 347–357.
† *Journal of Animal Ecology* (1946) **15**: 82–92.

* *Journal of Animal Ecology* (1946) **15**: 130–133; (1948) **17**: 155–157 and 151–154; (1949) **18**: 187–192.

Looked at another way, this scientific technique is the essence of amateurism in the sporting sense. Nine times out of ten the observer is alone when these things happen, and what fun is there in recording as certain an animal of whose identity you are not really sure? What fun in building up a theory if you are not convinced in your heart of hearts of the strength of the component bricks? In field natural history you have usually to play a lone round against a bogey of your own fixing, and the mass of printed observations upon which others may draw for generations depends on the integrity of the individuals who recorded them.

If the observer feels, as perhaps he may after the spate of books and papers published in recent years, that plenty of attention is being paid to the birds and mammals of this country, and that our reptiles and batrachians are so few, there is still one vertebrate field where new knowledge can be gained of a kind that is available for the other groups. Apart from the 'sporting' Salmonid species and the perch (*Perca fluviatilis*), most of the freshwater fish of Britain have not attracted any more study than is required to evolve techniques for catching them. The life history of the chub (*Squalius cephalus*), ruffe (*Acerina cernua*) and miller's-thumb (*Cottus gobio*), to name three species which are common in many parts of England is still largely a sealed book. We have little idea of the fluctuations in numbers of fish along the same stretch of river at different seasons, of their local movements, or of their daily routine. No harder to watch than many of our mammals, fish still have the attraction of a strange element for the observer to penetrate and offer a challenge to the whole gamut of spare-time, part-time and full-time naturalists.

Generally speaking, it is the small everyday problem which brings the best returns, certainly for the part-time observer, and he should have no difficulty, even in branches of natural history less highly organised than ornithology, in getting 'professional' advice and help through the nearest University, Training College, or Grammar School, or by membership of a live Natural History Society.

In conclusion I must make some comment on the problems put forward by Maxwell Knight in his article. Dismissing the young-swallowing adder and apple-sticking urchin as myths—in any case the chances against even a full-time worker finding a gravid adder at the critical moment in the field must be astronomical—we come to the drumming woodpecker. A microphone test *has* been made of this phenomenon in the great spotted woodpecker and the drumming was heard through headphones 40 yards away perceptibly before the airborne sounds reached the observer.* Dr. David Lack also reported† that beak marks had been seen on a popular drumming sight. When the "overwhelming evidence" of contact between beak and tree presented to the editors of the *Handbook of British Birds* is taken into account, the mechanical element in the performance is proved beyond reasonable doubt. Some hastily improvised experiments with an electric bell, a great tit's skull and a 4½ volt battery convinced us, when discussing this article, that the requisite carrying power could be produced without bringing in any vocal element. Nor, bearing in mind the remarkable demands made by birds on their bones and muscles in actions, about which there is no dispute, does it seem improbable that a species, which can peck a nest hole through live wood, should be able to stand up to the physical demands of purely mechanical drumming. Such problems are, however, of use in attracting to natural history a fresh type of mind, more usually at home in engineering and electrical hobbies; animal photography and the live trapping of birds and mammals are other fields in which the 'mechanically minded' have made important contributions.

The investigation of the perception by animals of fear in man seems to be quite impossible, even with full-time attention and the use of highly skilled laboratory techniques, for we have as yet no idea how to assess an animal's perception of a human emotion. It should be easier to investigate the sense of hearing in snakes, though this is hardly a field problem for British naturalists. The movement of amphibians to their breeding places also seems essentially a subject for professional research. If, as is possible, the orientation of these animals has something to do with humidity gradients, then its investigation will obviously be of a specialised character.

Naturally the rare, the spectacular and the exotic will always appeal to us, especially if our pursuit of wild life has in it an element of escape from what we imagine to be a humdrum existence. There is a strong case for a purely recreational interest in nature, but this has not necessarily anything to do with the field study of animals for scientific ends, which demands submission to a self-imposed discipline and recognition that the commonplace is ultimately more exciting than the unusual, and the abnormal only to be appreciated when the normal, from which it departs, is intimately known.

BRUCE CAMPBELL.

* Pullen, N. D. (1942), *British Birds* **37**: 175–176.
† *Ibid.* p. 236.

WILD ANIMALS IN CAPTIVITY—*Continued from p. 313*

man relationship, in the precision of the animal's achievements and in the pattern of group performances. Just as a composer using his special gifts chooses and combines the various instruments of the orchestra, so the trainer skilfully groups his animals, and by carefully arranging the interplay of their actions and counter-actions, using biological factors, produces the reaction from each of his animals that the performance as a whole requires. But it is doubtful whether many will go so far as the author in drawing this parallel between animal trainers and musical composers.

Many other fascinating topics are dealt with by Professor Hediger, but in the space at our disposal it has only been possible to refer to a few selected examples. There will probably be disagreement concerning some of his theories, but all those interested in either the care or behaviour of animals will find this book invaluable.

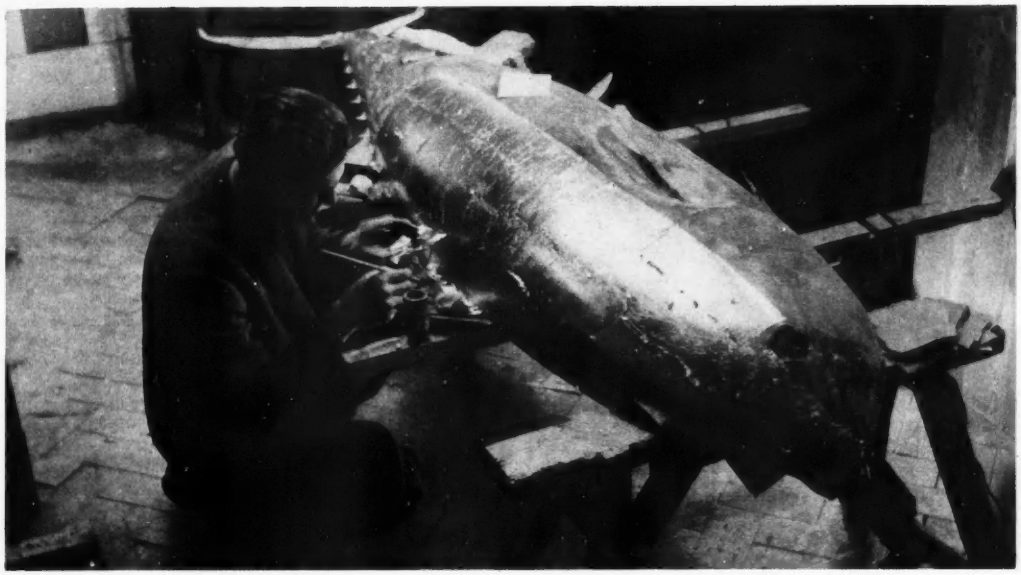


FIG. 1.—Silver metal leaf being applied to a plaster cast of a giant tunny fish. (Photo: *Illustrated.*)

The House of Gerrards

JOHN HILLABY, F.Z.S.

THE name of Gerrards, of London, the suppliers of biological material, is perhaps no less known than the index numbers of some of their stock supplies. It is on record that the words "11 a.m., practical, genitalia of Z276" has appeared on the notice-boards of medical schools, for Z276 has become synonymous with pickled dogfish through the years.

Gerrards are now celebrating their centenary. There are virtually two businesses under the control of the great grandsons of old Edward Gerrard, who turned his hand to the preservation of the "curious subjects of the animal kingdom" brought back, among others, by Trader Horn from the Congo in the days when Huxley was defending Darwin. In 1841, after five years employment in the museum of the Zoological Society, Gerrard was officially indentured as 1st Class Attendant to the great Dr. J. E. Gray, of the Department of Zoology in the old British Museum at Montague House.

Edward Gerrard catalogued Gray's collection of mammalian bones, a collection which soon rivalled the cabinets of Leiden and Berlin and eventually became the most complete in the world. The great anatomists needed great preparators, for the collectors were sending back shiploads of material from the tropics.

In 1850 old Edward decided to start a taxidermy business in the back-yard of his home at College Place in North London, and very soon he was being visited by Hunter, Waterhouse, Selous, Livingstone, Gunther and Rothschild. "A veritable poets' corner for renegades of all kinds," wrote Trader Horn, who was one of his earliest clients among ". . . all the Africa fellers there. You get your cheque plus some hearty entertainment, and off you go again to the ends of the earth for a few novelties. Everything gigantic was an attraction there. They liked breaking records, whether in the size of a sea lion, or a prehistorical egg or the colour of a precious stone. . . ." There was reason for the trader's uninhibited enthusiasm; he had just received a cheque for "the largest gorilla skull in the world" which he had picked up for three bottles of gin.

A small staff was trained to twist the hay cords and push them into position with the old stuffing irons, and before Mr. Edward died within a few months of his 101st birthday in 1910 he had seen his sons, grandsons and great grandsons in his workshops.

Business was equally divided between the preparation of specimens for museums and schools and doing work for sportsmen in the last great flowering of the safari. Pickled exhibits were certainly sold to universities, but the emphasis was on skeletons and skins. Under the father and grandfather of the present proprietors of the two businesses, the College Place workshops were filled with apes, oxen, rhinos, antelopes and large fish in orderly disarray. They brought back Galapagos tortoises for the late Lord Rothschild, made forty bearskins into a rug for Lord Kitchener and mounted literally thousands of masks of foxes in the hunting season.

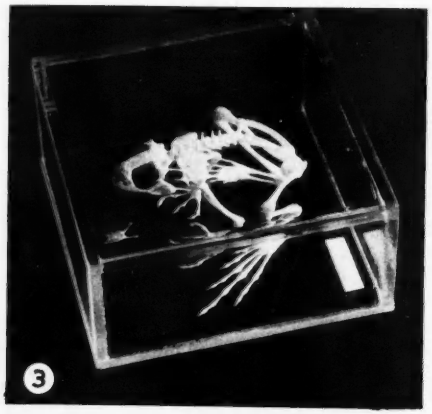
As the times changed they lent basking sharks to the film companies, and mounted prize greyhounds and a variety of celebrated animals from the Zoo, including, latterly, Lien Ho, the panda. Perhaps their most ambitious project was concerned with an 82-ft. long whale washed ashore at Wexford. The vertebrae were laid down like the

Fig. 2.—Specimens which are to be embedded are positioned in a tray containing the acrylic casting resin.

Fig. 3.—The skeleton of a common frog which has been dry mounted in a transparent plastic case to give complete vision from all sides.

Fig. 4.—A liver fluke embedded in a cast block of methyl methacrylate. Apart from preserving the specimens, the block enables them to be handled without fear of breakage.

All the photographs on this page are reproduced by courtesy of *British Plastics*.



keel of a ship, and the ribs built round it in sections before it was ready to be hauled off on traction engines and suspended on iron supports beneath the ceiling of the Whale Room at the South Kensington Natural History Museum. A giraffe ordered by a South African museum was too big to pass under the bridges on the way to the docks and had to be re-routed round bridge-free country before it reached the ship. At the destination it was not only necessary to remove the museum doors, but workmen had to burrow down into the foundations of the building to get the animal into the display hall in one piece.

Different specimens presented different problems. A 9-ft. tunny for Leeds University was found to be encased in a quarter of an inch thick corselet of ovoid scales which had to be hacked through with a saw before they could get at the bones. Air-dried skins of animals sent direct from the collecting grounds together with their bones and ligaments were among the daily incoming packages at College Place, where the taxidermists began to adopt the latest technique of the built-up papier mâché model with an enveloping skin on top.

Between the two world wars Gerrards' business was equally divided between taxidermy, skin and horn mounting conducted by Mr. Edward Gerrard junior, and the biological supply side in charge of the late Mr. Thomas Gerrard and Mr. T. Gerrard junior. In 1938, T. Gerrard & Co. Ltd. moved to separate premises in the Pentonville Road.

Within a short time it became apparent that only by planned departmentalisation could they cater for the multifarious demands of schools, universities and hospitals. The advent of the phase contrast microscope, for instance, complicated their preparation of slide fixatives: more chemists joined the staff. Stock dissection material such as dogfish, frog and rabbit were required in such quantities that arrangements had to be made to trawl the fish regularly in the Channel, and farm the rest in Norfolk. A technique of partly dissecting material before dispatch and the demand for fully prepared dissections for display led to an increase in the number of dissectors and preparators employed. They had to be trained as apprentices in the laboratories. There were few if any available from other sources.

It is surprising that there is not more competition in the business of biological supplies. A few naturalists sometimes provide cultures and local supplies of living material for, perhaps, one or two university departments, but the complex task of providing a wide range of material on demand can be gathered from the fact that it took four years experimentation to cultivate amoebae in Gerrards' laboratory. When the late Mr. Thomas Gerrard made a world tour of universities and hospitals he found that almost every institution was prepared to give orders at once from diatoms to whole skins of elephants—if they could be supplied promptly.

However, his plans for the large-scale exportation of material came to a dramatic end in 1940 when bombs gutted rather more than half the adjacent premises in the Pentonville Road.

The task of providing the J.B.S. stain for anti-malarial work in the field became a Government-ordained priority, together with other medical preparations and contracts from the Ministry of Supply. An unexpected consignment of reptiles was offered overnight from the Zoo who were asked to dispose of their potentially dangerous stocks. Servicemen continued to bring in animals from abroad, and these were sent out to the evacuated schools and university departments who were continually changing their addresses.

American medical service staff officers gave orders for the equipping of whole field and temporary army universities, a much-needed fillip for British goods and craftsmanship, the effect of which is still being felt in the dollar business today.

By the end of the war Gerrards' business was re-established on an almost entirely new basis. The stock supplies were still available: bones were still on sale from the £3 skeleton of a guinea pig to a £100 gorilla; preserved and partly dissected eyeballs, life histories of cockroaches and mosquitoes were in general demand, but the technological progress of the war was reflected in freeze-dried culture media, antioxidants in biological stains and chemical reagents, and brains mounted on Perspex.

The old technique of mounting specimens on gelatine in formalin-filled jars where they had to be topped up periodically gave way to transparent plastics as embedding materials, and an associated business for this purpose was started in Croydon.

In 1947 Gerrards investigated the properties of methyl methacrylate, largely because of its outstanding optical properties. The ideal was a permanent preservative and a mount that could be easily handled without the fear of breakage through dropping, a medium, in fact, which would neither evaporate nor suffer from discoloration.

Two methods of embedding are practised today—casting round the object without impregnation, and impregnating the object so that it becomes a fused solid mass in the block, with the specimen under view like a fly in amber. Up to twenty-four specimens are cast in the plastic syrup at the same time. Polymerisation is effected by the normal method of electric oven heating or the use of ultra-violet light. Heat and consequent shrinkage caused acute difficulties. Nor was bubble-free casting easy, but it is now possible with this method to mount almost any object—plants, parasitic worms, starfish, insects, embryos and pathological specimens in any size block.

Gerrards are now experimenting further with a variety of artificial resins and fibres for the manufacture of large biological and anatomical models: tsetse flies as big as pigeons, hydra a foot high, massive sections of human skin, human eyeballs and articulating knee-joints. For medical school purposes a considerable amount of living or osteological material can never be manufactured and supplies, like human skeletons from India and skins or preserved specimens of animals, still come in from abroad.

It is significant, perhaps, that in a world of diminishing fauna and diminishing incomes, the professional collectors, the sportsmen and the white hunters send in very little. Stock material is dispatched by institutions or by former students now with posts abroad who know what Gerrards want. Unusual specimens have to be specially ordered. Old Edward Gerrard would not know his new clients and the purposes to which they put their material today. He would be equally lost among the forty technicians in the Pentonville Road who are building up the curious subjects of the animal kingdom out of wood pulp, phenols and formaldehyde.

James Young: Father of Modern Transport

A. D. CUMMINGS

THE Petroleum Industry began in this country just over a hundred years ago. Though in later years it was to have such far-reaching effects on civilisation, this industry started from the simple desire to furnish a lamp oil that would be cheaper that the sperm oil then in use.

The following historic letter written on December 3, 1847, was the beginning of it all.

My dear Young,

You know that mineral naphtha is a rare natural product, no spring of it occurring in this country, all being imported from the Continent or Persia. Lately a spring of this valuable product has been discovered on an estate belonging to my brother-in-law (Mr. Oakes) near Alfreton, Derbyshire. It yields at present about 300 gallons daily. The naphtha is about the consistence of thin treacle, and with one distillation it gives a clear colouriess liquid of brilliant illuminating power. It dissolves caouchouc easily. My brother intends to set up a still for it immediately, but as they are iron-masters, this would be a separate industry, so I have advised them, if possible, to sell the naphtha in a crude state to chemical manufacturers and thus avoid carrying on an industry foreign to their occupation. Does this come within the province of your works? If it will do, I will send you a gallon for examination. Perhaps you could make a capital thing out of this new industry and enable my friends to do the same. You are aware that naphtha is now largely used for adding to the illuminating power of gas and that the residue is a valuable product.

The writer of this letter was Lyon Playfair, the chemist of the Geological Survey; it was addressed to his friend James Young, a chemical works manager in Manchester. There was an element of accident about the connexions between Oakes, Playfair and Young that is sufficiently remarkable when we consider the consequences.

The world might have waited a long time for the exploitation of petroleum had it not been that a coal owner was sufficiently interested to communicate with his scientist brother-in-law, that the latter should think of the possible uses of the discovery, and should wish to help a friend.

But for Young there would have been no petroleum industry at that time. Oakes and Playfair were men in comfortable circumstances and not particularly interested in developing the discovery themselves. Young decided there was something in it for him, after the famous chemical firm he worked for—Charles Tennant & Co. of Glasgow—had turned the idea down as too trivial to be worth their consideration, and went ahead on his own account. He was amply repaid for his enterprise, and after less than twenty years he was able to retire with a comfortable fortune.

As young men, Playfair and Young had been fellow students of chemistry under Professor Graham in Glasgow. Young had started as a carpenter who repaired apparatus, and Professor Graham made him his laboratory assistant. Other students in the same class were the brothers Thomson, James and William (later Lord Kelvin), and David Livingstone, whom Young in his prosperous later days was able to finance in his explorations. When Professor Graham moved to University College, London, he took Young with him, and after a period there, he put him in the way of getting a good post as manager of a chemical works.

After receiving the historic letter from Playfair, Young went over from Manchester to visit the Oakes colliery, where the oil had been found. He learned that the oil had been discovered in the following way. A shaft was being deepened in Old Deeps colliery, within a short distance from the Oakes house and on the edge of the Cromford canal, to reach a lower seam of coal. In the course of sinking the shaft they encountered some water, salt water, and this was run into the canal. Later the water decreased in volume and was accompanied by a thin black oil that floated on the water.

The oil, which had a peculiar odour that clung to the clothes of the men working in the new shaft, was allowed to run away to waste in the canal. It remained there on the surface and "after a strong west wind had been blowing for some days, it was driven up in considerable quantity into the blank end of Pinxton wharf. The boys in the neighbourhood found that it would blaze, and amused themselves by bringing hot coals and burning sticks out of the cottages so as to create a considerable light in the evening." News of all this reached Oakes' ears—together with a complaint from a brewery company drawing water from the canal that something was spoiling the flavour of their beer. So Oakes was prompted to write to Playfair to ask him what could be done about the oil.

On failing to interest Tennant & Co. in the business, Young obtained their permission to work the oil himself. He put his assistant, Meldrum, in charge of operations and made an agreement with Oakes on the following terms: Oakes was to supply the land, buildings, and apparatus necessary for the distillation, Young was to be in charge of the manufacture of such useful products as he could obtain from the crude oil (referred to in the agreement as "fluid bitumen") and should pay Oakes for coal, wages, damages, and losses plus ten per cent on the money spent on the works, the proceeds of the sales to be divided between them. At first, it seems, the saleable oils were naphtha and lubricants; paraffin for lamps and paraffin wax were not sold

Young's Paraffin Light & Mineral Oil Co. Ltd., Addiewell Works, West Calder, *circa* 1890.

until after 1856. Playfair says that once, during a spell of cold weather, Young brought him a sample of oil that had become turbid through the separation of soft crystals that he was able to identify as a substance, already known from other sources, to which the name of 'paraffin wax' had been given. Playfair gave a lecture at the Royal Institution on the oil discovery and lighted his reading desk on this occasion with a pair of candles made from Young's wax, the first paraffin wax candles ever to be used.

In a little over a year from beginning operations the flow of oil from New Deeps, as the new sinking was called, began to decrease. Young, alarmed for his new venture, began to seek other materials that might yield similar oil. He had the idea that petroleum might be formed by the underground distillation of coal seams by subterranean heat, and he tried distilling coal at the lowest temperature to cause decomposition. He did not succeed entirely to his satisfaction until Bartholomew, the manager of the Glasgow gas works, drew his attention to the remarkable Boghead cannel coal. This gave a good yield of oil (120 gallons from a ton) of a similar nature to the dwindling oil of Oakes's estate. In 1850 Young cancelled his agreement with Oakes, closed his first refinery, and set up a new works at Bathgate in Scotland to work the new material.

From his new works Young sold naphtha, paraffin oil and wax, and lubricants, He fought his way successfully through a long series of lawsuits that sought to prove that he only had the right to work coal on the lands from which he drew his raw material and that his Boghead cannel was not coal at all. In the courts many leading scientists gave evidence on one side or the other, and theories of coal formation were hotly debated while Young's fate hung in the balance. But the attempts to deprive him of the results of his labours in founding a new industry failed and he won heavy damages.

Unfortunately the new material also had a limited life. In 1859 the Boghead cannel was worked out and this time Young turned to oil shale, i.e. shale containing organic matter which furnished oil on distillation. There was, and is, good reserve of this, and though it only yields 20 to 30 gallons per ton of shale (which has to be mined like coal), Young was at last able to make his fortune and the industry he founded is still working.

Through its later application to the internal combustion engine, a development entirely unforeseen in Young's time, oil gradually became of immense importance to the civilised world. Young died in 1883 without seeing the oil he had discovered used for transport. He died in the conviction that his work had benefited humanity, a belief that could still be accepted wholeheartedly and without misgivings but for the application of oil-driven transport to purposes of war. Our need for oil in two world wars drove us to make an intensive search for oil in this country. In 1918, just before the First World War ended, a new oil discovery was made for the first time since 1847; a well at Hardstoft, near Chesterfield, and not very far from Young's original 'spring' at Riddings, yielded a small quantity. During the Second World War more oil, about half a million tons, was got from a small oilfield at Eakring in the neighbouring county of Nottinghamshire.

Hundred Years of Submarine Cables

ON August 28 it was exactly one hundred years since the laying of the first submarine telegraph cable across the Straits of Dover by the brothers J. W. and Jacob Brett, an event which was to mark the birth of international telecommunications.

In celebration of the centenary and to demonstrate the remarkable facilities for world-wide communication which are now available via the network of submarine cables, a special exhibition at the Science Museum was formally opened by the Postmaster-General on August 28, 1950.

The exhibition briefly describes the beginnings of land telegraphy and the work of Cooke and Wheatstone from 1837 onwards. The laying of the first primitive submarine cable in 1850 and the subsequent early Atlantic cables are illustrated by appropriate exhibits, and the growth of the comprehensive cable network which now reaches to all parts of the world is described.

Also shown is the development of submarine cables throughout the century, and modern practice and future trends are specially illustrated together with exhibits of equipment and methods employed in cable manufacture and repair. One section includes cable laying and cable repair ships with ancillary equipment.

A feature of the exhibition is the working exhibits and, during certain times, it is possible to witness the transmission of messages to overseas destinations and to receive a reply within a few minutes.

A handbook entitled *100 Years of Submarine Cables* has been prepared by G. R. M. Garratt, M.A., M.I.E.E., of the Science Museum, and is on sale at the exhibition, price 2*s.* 6*d.* The handbook traces the history of submarine cables from 1850 and includes a chapter in which the future trends are briefly discussed. While the handbook has been prepared for publication to coincide with the exhibition, it will nevertheless be a reference book for the future. There are chapters dealing with the manufacture and development of cable and terminal equipment, cable laying and cable repair ships, and the book also stresses the importance of this branch of our communication system.

The exhibition was opened to the public on August 29 will remain open until October 28.

Also in commemoration of the laying of the first cross-Channel telegraph cable, the B.B.C. transmitted on August 27 the first cross-Channel television programme from Calais. The town had arranged a special entertainment in the square in front of the town hall and viewers in England enjoyed good reception of the scenes of celebration.

Far and Near

Uranium Found in North Wales

At the end of August the D.S.I.R. announced that a uranium deposit of moderately high radio-activity has been discovered in the Dolgelly black band shales of North Wales. Possibly a million tons of uranium are present in sub-marginal grade rocks carrying 80 grammes a ton. It is said that the deposit is of a very low-grade ore, 80 grammes a ton, and not economical to work in normal circumstances. The normal economic grade contains at least 150 grammes.

Professor Janossy Returns Home

After thirty years' absence Professor Lajos Jánossy, internationally recognised as an authority on cosmic rays, has given up his professorship at Dublin University, and returned to Hungary.

New Director of the Science Museum

Dr. F. Sherwood Taylor has been appointed director of the Science Museum, South Kensington, and will take up his duties on October 1 next. Dr. Sherwood Taylor has been curator of the Museum of the History of Science at Oxford since 1940. His age is 52.

Professor Oliphant takes up Appointment

Professor Oliphant has arrived in Canberra to take up his appointment as director of the Research School of Physical Science of the Australian National University. Although it will probably be some years before the school is finally established, Professor Oliphant will be engaged in the meantime on the construction and installation of Australia's first cyclotron. It is proposed to build two cyclotrons. The first will be a small replica of the final machine, and it will be used in an experimental capacity in order to discover any possible faults in the second and larger cyclotron.

The larger cyclotron will be the most powerful of its type in the world with a potential of approximately 200,000,000 volts.

Guided Missile Research to be Intensified

The Air Ministry and the Ministry of Supply announce that Air Chief Marshal Sir W. Alec Coryton, Controller of Supplies (Air), Ministry of Supply, is to be Chief Executive, Guided Weapons, a post created at the Ministry of Supply with the object of accelerating and co-ordinating all work on the research, development, and production of guided weapons.

End of Customs Dues on Scientific Materials?

An international agreement which will allow a wide range of educational, scientific and cultural materials to move across frontiers free of duty has been circulated by Unesco to its fifty-nine Member States. The text of this convention was unanimously approved by Unesco's General Conference recently at Florence.

The agreement will come into force following ratification by ten countries.

Contracting States will abolish duties on books, newspapers, magazines, music scores, maps, charts and travel literature. Duties will also be lifted from many materials consigned to approved educational, scientific and cultural institutions. The agreement will also permit the free importation of paintings, drawings and sculpture, and of newsreels, educational films and sound recordings. Items covered by the convention include scientific equipment, and industrial or engineering plans and designs.

Ornithologists Confer in Sweden.

The Tenth International Ornithological Congress was held in the university town of Upsala in Sweden during June. It was the first to take place since the one held at Rouen in 1938. Ornithologists from 28 countries were present, to the total of 370, of whom 78 came from the United Kingdom. The Congress met under the presidency of Dr. Alexander Wetmore, Director of Washington's Smithsonian Institution, who delivered an inaugural address on recent additions to our knowledge of prehistoric birds. It is an interesting illustration of changing values in ornithology that only one other paper out of the hundred presented to the Congress dealt with palaeontology proper, though Dr. R. C. Murphy discussed the remarkable moa deposits of Pyramid Valley Swamp, New Zealand, which are geologically speaking of recent date.

An outstanding piece of field research was described on the opening day of the Congress by the Swedish ornithologist, P. O. Swanberg, in his study of food storage, territory and song in the thick-billed nutcracker (*Nucifraga caryocatactes*) It has long been known that certain populations of the western race of the nutcracker, being unable to obtain the seeds of the Arolla pine (*Pinus cembra*) have succeeded in adapting themselves to a diet of hazel nuts (and in doing so have evolved a thicker bill than their eastern fellows, which is better able to crack the thicker shells of these nuts). As a result, in parts of western Europe where the Arolla pine does not grow, nutcrackers are confined to the comparatively few places where hazel trees grow in quantity not far from a reasonably sized coniferous wood. One such population, on a hill called Billingen in Central Sweden, has been intensively studied by Swanberg, where pine on the granite hill-top provides the nesting territories, while hazel growing on the limestone flanks of the hill supplies the food. Swanberg has been able to prove that the main purpose of territory in the nutcracker is to provide a place for storing hazel nuts. These are collected during the late summer and early autumn and buried in selected spots throughout the territory, and on these stores the birds rely for the bulk of their sustenance during the rest of the year. The birds have a quite remarkable memory for the location of these stores, even under several feet of snow, and close observation has shown that their excavations go straight to the right spot in 85% of cases. There is almost none of the territorial disputing so common in small passerines, and it is clear that this must be due to the fact that there is no value in acquiring another bird's territory when the whole value of a territory consists in being familiar with every inch of it.

Many interesting papers were concerned with migration, and one of the pieces of research described was that of the German Dr. G. Kramer, who has shown that captive migratory birds orient themselves, so far as can be detected, only to the sun. The Swedish ornithologist G. E. Rudebeck described the remarkable migrations to be observed at the south-westernmost point of Sweden, thousands of buzzards and other birds of prey passing within the course of a single daylight hour during favourable weather conditions. R. E. Moreau, editor of the British Ornithologists' Union's journal *The Ibis*, challenged prevailing ideas about the supposed part played by the Ice Age in the origin of migration. He maintained that the Palaearctic Region had tended to be over-emphasised in the discussion of how migration began, and after giving suggestive examples of migration in other parts of the world, including the tropics, said that he agreed with Mayr and Meise that migration was far older that the recent Ice Age, and was in fact the result of adaptation to seasonal differences in the ability of the breeding area to provide enough food to support the total population.

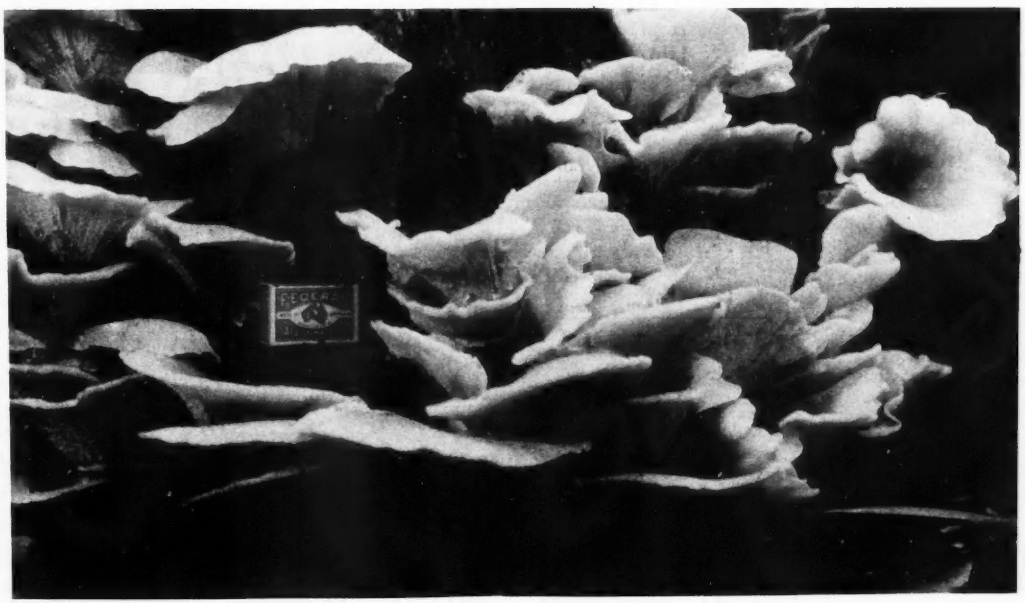
Of the papers on bird behaviour, one of the most striking was Professor Tinbergen's film to demonstrate the nature of the stimuli releasing the begging response in young herring-gull chicks. This showed clearly that the red spot at the tip of the parent's bill was the most important factor, the colour and even shape of the bill being almost immaterial if the red spot was present, whereas a bill of the right shape and colour with no spot, or a differently coloured one evoked comparatively little interest in the chick.

H. Poulsen (Denmark) gave an important contribution on the parts played by inheritance and learning in the song of the chaffinch. He showed that young chaffinches learn their song from adults in the very early spring at about the time when general chaffinch song first begins, and that if they are kept out of earshot of other chaffinches until about April they lose the capacity to learn, and are incapable of more than the rudimentary attempt at song which may be regularly heard from young birds in the autumn.

On the subject of bird distribution, some striking observations were submitted. Dr. Salomonsen (Denmark), for instance, described how the fieldfare had colonised southern Greenland in 1937, as a result of a party being swept out to sea by a south-easterly gale, carried from Norway to Greenland, and settling down as a resident colony in some birchwoods on some sheltered fjords. Dr. John Berry, Director

The Ghost Fungus

An Australian reader, Colonel Allan Foott, of Turramurra, has sent us these pictures, the most impressive photographs of a luminous fungus we have seen. The fungus is *Pleurotus lampas*, commonly known as the Ghost Fungus. It is fairly common in forest country throughout south-east Australia. By day the fungus is not impressive, but its fruit bodies are most striking objects at night when they emit a silvery light by which it is possible to read a newspaper. The top photograph was taken using the plant's luminescence as the sole light-source; film of Weston speed 100 was used, and the exposure was one hour. Some British species of the genus to which the Ghost Fungus belongs are luminous; luminous species also occur in the genus *Panus*. Luminescence is also exhibited by the Honey Fungus *Armillaria mellea* and *Xylaria hypoxylon*; the mycelia, not the fructifications, of these are luminous.



of the Nature Conservancy in Scotland, related how a flock of barnacle-geese, reared in captivity on the Tay and allowed their liberty, had migrated to Norway, apparently started to breed there, and were returning to visit the Tay as ordinary winter visitors. This was all the more remarkable since normally barnacle-geese do not breed in Norway, or indeed any nearer to it than Spitsbergen.

The effects of the gradual warming up of the climate of northern Europe were described for their respective countries by Dr. F. Gudmundsson (Iceland) and Dr. E. Merikallio (Finland). During the past hundred years, and especially since 1920, the climate of Iceland has become two or three degrees warmer in the winter and a little less than this in the summer. As a result seven new breeding species, including the herring-gull and the starling, have arrived in Iceland from the south, while arctic-breeding species such as the little auk are retreating. In the Finnish birch-forests the brambling is retreating north and giving way to the chaffinch coming up from the south.

Colonel R. Meinertzhagen, the British representative on the Permanent Executive Committee of the Congress, gave a paper on desert coloration, as a result of his recent visit to Arabia. He suggested that camouflage was not the whole explanation of the special sandy coloration to be found in so many desert birds, as in many cases the birds did not crouch when alarmed, but moved about, ran and sat upright, thus taking no advantage of their cryptic coloration. He thought that a more likely explanation was that the sandy colouring was more resistant to the heat and glare of the sun.

At the close of the Congress it was announced that the 11th Congress would take place in Switzerland in 1954 under the presidency of Dr. A. Landsborough Thomson (U.K.). Dr. Thomson is Deputy Secretary of the Medical Research Council and is the leading British authority on bird ringing and migration.

Night Sky in October

The Moon.—New moon occurs on Oct. 11d 13h 33 m, U.T. and full moon on Oct. 25d 20h 46m. The following conjunctions with the moon take place:

October				
10d 02h	Saturn in conjunction with the moon	Saturn	2	N.
10d 13h	Mercury ,, ,,	Mercury	3	N.
15d 09h	Mars ,,	Mars	4	N.
20d 15h	Jupiter ,,	Jupiter	2	N.

In addition to these conjunctions with the moon, Mercury is in conjunction with Saturn on Oct. 6d 08h, Mercury being 0·3 S.

The Planets.—Mercury is a morning star, rising at 4h 20m and 5h 15m on Oct. 1 and 15, respectively. As the planet is in superior conjunction on Nov. 1, it is invisible at the end of the month. Venus rises an hour before the sun at the beginning of October and about 45 minutes before the sun in the middle of the month, after which it draws rather close to the sun for favourable observation. Its stellar magnitude is −3·4, and practically all the illuminated disk is visible. Mars is an evening star, setting at 19h 25m, 19h, and 18h 45m at the beginning, middle, and end of the month, respectively. Notice that the planet is very close to α Scorpii (Antares) about Oct. 6, and as they are both ruddy it is easy to confuse one with the other. After the above date Mars moves slowly east of Antares. Jupiter, in the constellation of Aquarius, but not very close to any bright star, sets at 2h 15m and 0h 10m on Oct. 1 and 31, respectively, and is visible for the greater part of the night. Saturn rises at 4 h 45m, 4h, and 3h 10m, on Oct. 1, 15, and 31, respectively, and is close to β Virginis during the first week in the month, from which it slowly separates, moving eastward.

Those who are interested in occultations will have an opportunity during October to see a large number of occultations of stars in the constellation of Taurus. About sixteen occultations take place during the month, nearly half of them occurring in the constellation of Taurus, but we shall notice only the brighter stars—none fainter than magnitude 4. The times given are for Greenwich, but are approximately correct for other places in the British Isles. D and R denote disappearance and reappearance, respectively.

The stars that will fulfil the above condition are 17, 20, η and 27, and the date is the same for all, Oct. 28; the times are as follows: 2h 58·8m (D) and 4h 18·2m (R); 4h 02·4m (D) and 4h 40·3m (R); 4h 36·1m (D) and 5h 40·0m (R); the last star on the list, 27, just grazes the limb of the moon, and so it can scarcely be called an occultation. Each star appears to approach the moon on the left side as you face our satellite, but of course it is the motion of the moon as she revolves around the earth in an easterly direction that is responsible for the occultations. It will be noticed that the occultations do not all last the same time; the time depends on the portion of the moon's rim where the star appears to touch it. If this is near the top or bottom the time will be comparatively short.

Plants for Colonising Waste Land

INCREASED human mobility and a wider distribution of wealth and leisure have helped more people to understand how small this island is, and with these developments has come a more general (if superficial) appreciation of 'natural' beauty. The ghastly scars made by industry on the face of the earth were generally taken for granted by our great-grandfathers, but now they are seen as an offence which should be remedied. The latest joint publication of the Commonwealth Agricultural Bureaux, *The Establishment of Vegetation on Industrial Waste Land*, by R. O. Whyte and J. W. B. Sisam, deals with a most important aspect of the problem, which is defined as "the establishment of any type of vegetative cover, whether for the sake of amenity or for economic return, on the sterile and sometimes toxic medium provided by the waste material of industry which is deposited on the land surface." Though slim, the book includes accounts of work done in several countries, but more than three-quarters of both text and illustrations are devoted to Great Britain. Some of the photographs emphasise the mess made by industrial waste; others how slowly the waste land weathers and becomes suitable for colonisation by such plants as colts-foot and willow-herb; and others show what man can do and has done.

The variety of scars to be healed or hidden is very great. Most people will think first of colliery tips and post-war open-cast coal mining, but there are old slate workings in Wales, china clay heaps and pits in Cornwall and many other eyesores. Among the worst are some of the gravel pits in the Thames Valley and ironstone workings in the East Midlands. (Since this publication has appeared there has been an official statement that nearly all ironstone workings in the East Midlands are to be completely restored by replacement of topsoil—but this presumably applies more to future than to past workings.) Where topsoil replacement is impossible, the technique of reclamation is based either on the ecology of pioneer plants on poor soil or on the improvement of the soil by the incorporation of appropriate organic matter and artificial fertilisers before planting or sowing. Details and objects of reclamation may vary widely. In one place waste ground may be best levelled and converted into a playground or park; in another it may be converted into grazing for farm stock; in another—the largest category—the planting of trees offers the best hope.

In the establishment of trees there is a considerable adverse factor: children. And a sentence from the foreword may be quoted: "People accustomed to living among derelict land and spoil heaps will probably have to be educated to appreciate the value of a green view from their kitchen windows." The best safeguard against damage by children is probably to associate local schools with the actual work of preparing the ground and planting and tending the trees.

Messrs Whyte and Sisam's book keeps to its title and is not concerned with deciding what is the best use that can be made of particular waste lands.

The volume contains several tit-bits of curious information. In Glamorgan a lucerne plant was found to have roots which penetrated the poorest colliery refuse to the water supply 30 feet below. Under certain conditions toxic gas (or gasses) escape from quite old tips in Wales, and vegetation is injured and birds killed. The temperatures of tips may be very high: in Scotland tips have blazed on the surface more than three years after the closing of a pit, and when a shaft was driven into one 20-year-old tip, men could work there for only one minute at a time, even though there was special spray-water cooling.

The Americans have been more strenuous in reclamation than we have, though waste land looks worse in a small island than on a great continent. A research fellowship on the re-vegetation of spoil mounds exists at Purdue University, and in the state of Illinois over 11,000,000 trees of different species have been planted on 10,725 acres of spoil banks.

J. D. U. WARD

The Bookshelf

A Camera in Antarctica. By A. Saunders. (London, Winchester Publications, 1950, pp. 160, 21*s*.).

ANYONE with personal experience knows that Antarctica offers the photographer some of the world's most intriguing subjects under the most exasperating conditions. Sudden mists; intense glare from ice and snow; the fantastic tricks played by streaks of reflected light or vagrant ice particles; and the clouding-up of lens at the crucial moment or the sluggish behaviour of shutters—all contrive to present the polar cameraman with inexorable snags. However, in *A Camera in Antarctica* A. Saunders shows himself a master of his craft despite Nature's trickeries.

As photographer and a member of the scientific staff of the research ship *Discovery II*, Mr. Saunders spent fifteen years down south. His book teems primarily with facts about the animal and bird life of this cruel yet fascinating region. And though the simply written text makes capital reading, it is outshone by the seventy-two accompanying photographs. These, the outcome of hours and days of patience, record the White Continent's grim but arresting face, and rank among the most excellent yet brought from Antarctica.

The Human Species. By Anthony Barnett. (London, Macgibbon and Kee Ltd., 1950, pp. 280, 16 plates and numerous text figures, 18*s*.)

IN the words of its author, "this book describes some of the contributions that biological knowledge can make to contemporary problems. It has been written, and will be read, at a time of social upheaval, and it has not been designed as a detached, disinterested account of man such as a biologist might give of a dung beetle or an earthworm." Some will regret the absence of such detachment on the grounds that without it the name of science can be used to cloak dubious propaganda; on the other hand it has to be admitted that the social relevance of science is impossible of exposition without the consideration of those forces that contend within society. The author has selected his facts fairly enough, but in their interpretation the operation of prejudice is sometimes evident.

The writing is lucid and readable, though at times the style verges on the uncompromising and dogmatic. The text is up to date to a marked degree, and it is well related to the general reader's everyday experience. The results of biological inquiry in relation to conception and growth, human evolution, racial differences, sex-differences, food production, health and population statistics are all presented in a lively and relevant fashion.

The author exhibits an undeclared bias towards the environmentalist interpretation of man. Despite references to the "abilities of specially gifted persons", and to the fact that "each individual is genetically unique" the tendency is to present heredity as opposed to environment, with heredity of little practical significance for human betterment. Class differences and race differences as such may not be inherited, but many of the differences between individual men are of genetic origin and capable of differential transmission to ensuing generations. Again, trial by champions is not the only way in which to compare group performances. The inequality of the sexes is treated with greater fairness. It would seem that, despite the warning he gives concerning the confusion that has grown up between the idea of genetic inequality and the existence of social inequality of opportunity, the author has tended to perpetuate that confusion. If the reader uses this book in conjunction with Alan Dale's *Social Biology*—where the bias tends to be towards a genetic interpretation—he should be able to arrive at a balanced approach to these very controversial questions.

One could wish for more about the distinctive characteristics of scientific methods of investigation, and concerning the criteria of validity employed. We are however, appropriately reminded that "there is still nowhere today a widespread understanding of scientific method, even among those with a superior education, and there will probably be none until children have the opportunity to practice it in school. At present education remains in the pre-scientific phase: we are told what we ought to think, instead of having to discover things for ourselves and exercise our powers of criticism."

When the author attempts to diagnose the causes of social evils his interpretation is largely in terms of economic determination, sometimes at the cost of ignoring other factors. Thus in regard to Marx's statement that "all progress in capitalist agriculture is a progress . . . in the art of robbing the soil" no consideration is given to the possibility that 'commercial' rather than 'capitalist' might be the more appropriate adjective. Similarly the utilitarian origin of biology tends to be overstressed, though other origins are in fact acknowledged.

Enough has however been said to indicate the great interest of this book, its topical relevance and general suitability of style for the ordinary reader. Its format is very pleasing, and, whilst the subject receives proper presentation by way of figures, the book succeeds in conveying something of the atmosphere of a good monthly or quarterly journal in which illustrations and text are skilfully linked.

If this book is widely and critically read —and it is to be hoped that many will become acquainted with its content of fact and the numerous shrewd observations thereon—it will contribute greatly to the development of an informed public opinion about the use and abuse of biology in the world today. M. H. C.

Text-book of Inorganic Chemistry. By J. R. Partington. (London, Macmillan, 6th edition, 1950, pp. 996, 25*s*.).

PROFESSOR Partington's text-book has now reached its thirtieth year. It is not his oldest book, since his *Textbook of Thermodynamics* (now called *Chemical Thermodynamics*) has the advantage by eight years, but it is the book which has brought the name of Partington to the knowledge and gratitude of the widest circle of his readers.

Partington stems from the school of Roscoe and Scherlemmer at Manchester, and the earlier editions of the *Inorganic Chemistry* echoed a part of their compendious work. His location in the north-west of England had an influence also. This was the home of our heavy chemical industry and the practical applications of chemistry continually find mention and their demands on theory repeatedly emerge.

The German influence on his work may be seen in his close interest in Nerust's *Theoretical Chemistry* and *Thermodynamics of Technical Gas Reactions* by Haber. These play an important role in inspiring his *Textbook of Thermodynamics*. During the 1914-18 war the advances in some sections of German industrial chemistry caused worry in Great Britain and Partington spent much time in investigating problems concerned with the nitrogen industry.

In 1918 he produced *The Alkali Industry* which gave a scientific introduction to the heavy chemical industry. This survey demonstrated the relation of chemical thermodynamics to a wide range of practical problems of commercial significance. In one way it marked a crossroads in its author's life and represented the limit of his approach to industry.

1921 saw the publication of the first edition of *A Text-book of Inorganic Chemistry*. The academic life tightened its grasp. From now on there was to be a constant stream of new books and new editions. The Department of Chemistry at East London College was to feel the effect of a strong dose of physical chemistry flavoured with inorganic chemistry and technical applications.

The quiet voice and the dry Mancunian humour have had obvious influence. On the academic side, successors in print have emerged both at home and in the U.S.A. In industry the emphasis on physical chemistry and its application has led many old students into the realm of chemical engineering.

The newcomer to Partington should be in no doubt about the value of this book as an addition to the shelf. The satisfied user of an earlier edition is recommended to examine the numerous changes and additions.

Faraday's Discovery of Electro-Magnetic Induction. By Thomas Martin. (London, Edward Arnold, 1949, pp. 160, 9*s*.)

THE story of Faraday's electro-magnetic researches is one of the most important in the whole history of science, both because it throws light on how scientific discoveries are made, and because of the far-spreading effects that flowed from the discoveries. Since Faraday kept a remarkable scientific diary, this story can be

followed in far more detail than most; and the diary was, of course, made generally available under Mr. Martin's editorship some years ago. However it takes time to pick out the electro-magnetic story from the bulk of the diary. Now Mr. Martin's latest book does this for us. It can be used, by those who are short of time, as a substitute for reading the diary (and other sources); or, by those who want to delve deeper, as a guide to the relevant parts of the diary. It provides a nearly ideal account of the progress of Faraday's own work, though less is said than one would wish about the broader background against which the research was done.

S. LILLEY.

The Horticultural Notebook. By J. C. Newsham, revised by W. E. Shewell-Cooper. (Technical Press, London, 1950, pp. 418, 10*s*. 6*d*.)

OVER forty-five years ago the head of the Monmouthshire Farm Institute, J. C. Newsham, wrote a reference book for all interested in the "Science and Practice of Horticulture". The result was *The Horticultural Notebook*, which has been reprinted many times since its first appearance. W. E. Shewell-Cooper, with the assistance of members of the staff of the Horticultural Educational & Advisory Bureau, Swanley, and others, has revised the book to make this new edition of the pocket encyclopaedia remarkably up to date; one finds in it, for instance, notes about such things as HETP, Parathion, hormone sprays, etc. It is to be thoroughly recommended to gardeners, both professional and amateur, for it contains a vast amount of information which is conveniently arranged and indexed, much of the information being tabulated.

The aim of keeping this work up to date seems to have been achieved mainly by the simple addition of new facts: it might be a good idea if the editor of the next edition cut out some of the somewhat unfruitful old wood which has accumulated over the years.

The Acceleration of Particles to High Energies. (London, Institute of Physics, 1950, pp. 58, 10*s*. 6*d*.)

PROGRESS in our knowledge of atomic nuclei depends to a great extent on the construction of 'atom smashers', *i.e.* machines for accelerating particles to high energies. Of these, the cyclotron has become widely known, but a number of other accelerators have recently gained increased importance. They fall roughly into two groups, depending on whether the path along which the particles are accelerated is circular or straight. The first group contains cyclotrons, betatrons and synchrotrons; machines of this kind contain a large magnet which serves to wind up the long acceleration path into a moderate volume. Straight accelerators either employ a large electrostatic potential or high-frequency potentials; the latter system is usually denoted by the unhelpful phrase 'linear accelerator'.

The great variety of machines makes it difficult for any one person to master the whole field, and fully justifies the way in which the subject has been divided between several authors, all of them well-known authorities in their special field. The book is based on papers given at a convention of the Institute of Physics, held in Buxton in May 1949. It gives an excellent survey of the whole field of particle accelerators, sufficiently detailed to be of value to the specialist; yet each article starts in a sufficiently elementary way to be of use to physicists or engineers with no previous knowledge of accelerators. Some familiarity with simple mathematics and physics is, however, assumed, and the book cannot be classed as 'popular'. The presentation is clear and good throughout; in particular the first article (on cyclotrons, by Prof. J. Rotblat) is a paradigm of straightforward, clear and readable exposition.

The text is supplemented by over a dozen diagrams and about a dozen well-chosen half-tone plates; each chapter is followed by a list of references. There are four chapters: "Cyclotrons" (by J. Rotblat), "Betatrons and Synchrotrons" (by F. K. Goward), and "Electrostatic Generators" and "Linear Accelerators" (both by E. S. Shire). These four chapters form the body of the book; they are preceded by a short foreword by Prof. M. L. E. Oliphant (himself a pioneer in the development of accelerators, and still in the front line) and followed by a lengthy discussion in which many finer points of interest to the specialist are brought to light. It is a pleasure to note that there is both a subject index and a name index, and the general appearance of the book is attractive.

O. R. FRISCH

Mathematics and the Imagination. By Edward Kasner and James Newman. (G. Bell & Sons, London, 1949, pp. xiv+380, 15*s*.)

THERE is a steadily growing supply of books that try to explain mathematics to the layman—explain, not its techniques, but its spirit, outlook, problems, and objectives. And the standard is gradually rising. *Mathematics and the Imagination* is another useful step towards the ideal, though it by no means attains it.

To begin with its deficiencies, quite apart from the intrinsic difficulties of the subject which must now and again defeat the understanding of most readers, there are occasional avoidable obscurities, which arise from carelessness or undue brevity: I could not relate the description of the Chinese ring puzzle on p. 169 to the figure; the description of the 'criss-cross curve' (354–5) is almost incomprehensible. More seriously, the arguments against the subjective theory of probability are mostly beside the point; mathematical paradoxes are treated with a triumphant air of implying that they show how foolish is the ordinary view of nature rather than how inadequate is the present state of mathematical science.

But when allowance has been made for such faults, we are left with a book that takes the reader for an extraordinarily stimulating lightning tour through Mathematical Wonderland. He will get only a tourist's view, but even that can be superior to the view of a local inhabitant who has spent his life tilling one field only of the mathematical commonwealth and has seldom even gone on a day's excursion to its other parts. The mathematical equipment demanded is small; and though a more learned reader may get more from it, one who has learnt a little school algebra and geometry, with preferably a smattering of calculus, will emerge from the book highly stimulated.

S. LILLEY.

Tropical Aquariums. By Ian Harman. (London, Sidgwick & Jackson, 1950, pp. 128, 6*s*.)

THE author says that the purpose of this book is to encourage the beginner and from the point of view of the written matter he will undoubtedly succeed. The novice is given advice on selecting tanks and preparing them for fishes. A list of aquatic plants, with descriptions of each species and notes on their suitability for aquaria, is given and although *Elodea densa* is now known as *Egeria densa* this fact will probably not worry the beginner. Buying fishes, keeping the aquarium clean and feeding, receive adequate treatment although it is not true to say that only a few aquarium fishes are omnivorous. The merits of electric, oil and gas heating systems are discussed.

Although the author does not appear to be an ichthyologist (he mentions *Limia* family instead of *Limia* genera, central instead of pelvic fins, and the 'great intelligence' of Paradise fishes), he does give the novice a good idea of representative aquarium fishes. Unfortunately the illustrations are poor and I had difficulty in recognising some of the species. Good illustrations are essential for a beginner's book.

R. J. A.

Great Men of Science. A History of Scientific Progress. By Philipp Lenard. (London, G. Bell and Sons Ltd., 1950, pp. 382, 15*s*.).

THIS is a reissue of a book first published in 1933. Professor Andrade, who worked under Lenard at Heidelberg, has not altered his original introduction, perhaps feeling it better to leave well alone. For Lenard was a famous German physicist who became notorious because of his advocacy of Aryan physics in his extreme old age—he died in 1947. This book was written before 1933 and is a notable contribution to the biographical side of the history of science. Sixty-four scientists are dealt with in chronological order, from Pythagoras to Hasenöhrl, who was killed in 1915 at the age of 41. According to Lenard, Hasenöhrl derived the mass-energy relationship before Einstein (whose name Lenard studiously avoids) and was responsible for an immense amount of original work for which nobody has bothered to give him credit.

This is no anecdotal history, for the emphasis is always on the nature of the work done, and it is as factually accurate as an experienced researcher like Lenard could make it.

C. L. BOLTZ.

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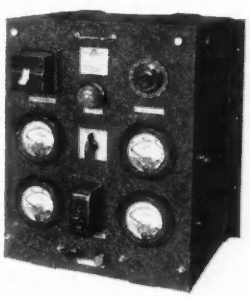

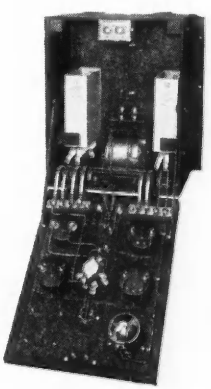

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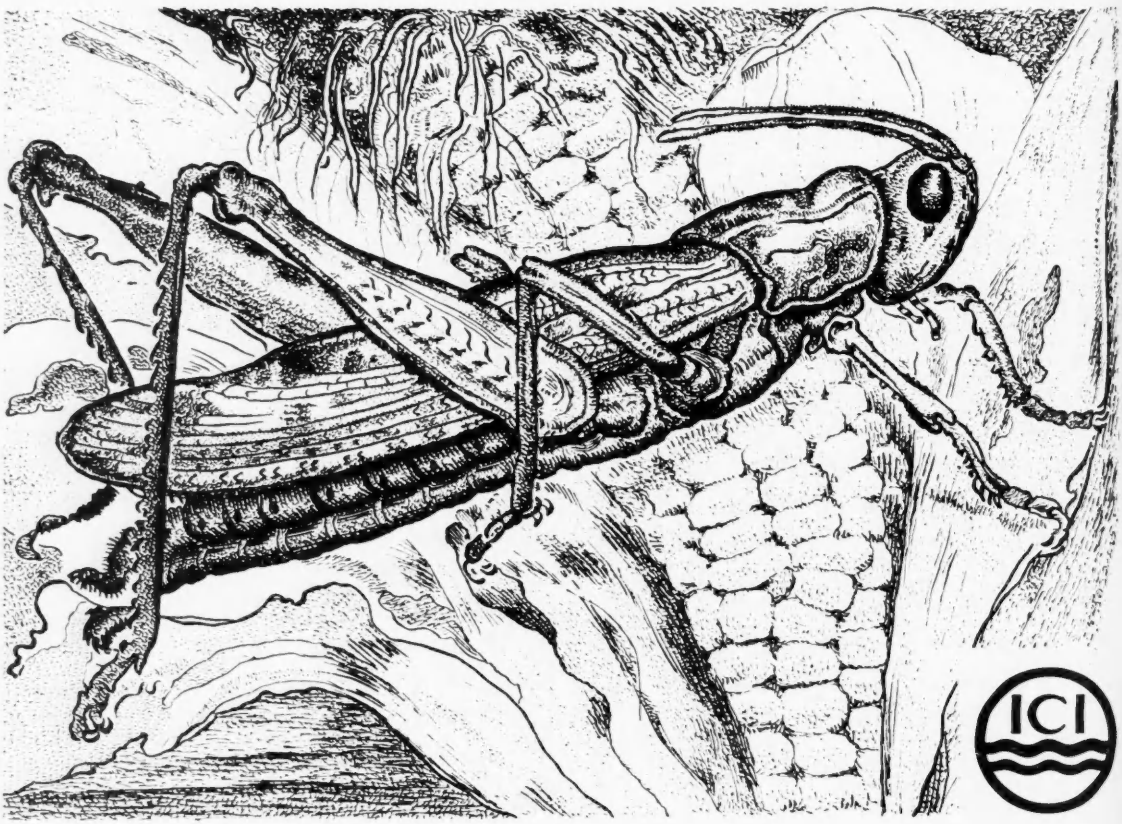

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